THE GANGA
A SCIENTIFIC STUDY

Based on an Integrated Research Programme carried out by 14 Universities located in the
Ganga Basin sponsored and funded by the Environment Research Committee
and
The Ganga Project Directorate
Ministry of Environment & Forests
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New Delhi

THE GANGA

A Scientific Study

Editors

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To The Late Dr C. R. KRISHNA MURTI
who spared no efforts
for the success of the Project
and in finalizing
this Volume

Prof. M. G. K. Menon

प्रधान मंत्री के वैज्ञानिक सलाहकार
और
सदस्य
योजना आयोग
योजना भवन
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March 20 ,1989.

FOREWORD

The Sixth Plan recommended the involvement of institutions of higher learning in undertaking coordinated research projects designed to study problems relevant to development. At the suggestion of Dr. M.S. Swaminathan, the then Member of the Planning Commission, a Conference was convened on 21st December, 1981, of Vice-Chancellors of Universities and Directors of Research Institutions all along the Ganga, representatives of the Departments of Environment, Science & Technology, Ministry of Education, U.G.C. and experts from the Planning Commission. The concept of instituting a coordinated scientific study of the Ganga in all its aspects emerged out of the deliberations of this Conference; and the nation is indebted to Dr. M.S. Swaminathan for his initiative that resulted in this activity.

The work related to this programme was supported and progressed in the Planning Commission for sometime, but was thereafter transferred, at my instance, to the Ministry of Environment and Forests which has since taken responsibility for the Ganga Plan of Action. A Working Group on the Ganga Basin Ecodevelopment with Dr. C.R. Krishna Murti as Chairman was set up by the Ministry of Environment on August 31, 1982.

The coordinated study was launched in the latter part of 1983 and became effectively functional in 1985. The three year study was aimed at an integrated approach to some of the key problems related to the quality of water of the Ganga, the interaction between the biotic and abiotic characteristics of the river in self-regeneration even after accepting heavy loads of environmental pollutants. The work involved the participation of 14 Universities located in the Ganga Basin. The data generated out of this major multi-disciplinary effort has been evaluated and presented in this book.

Prof. M. G. K. Menon

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As Chairman of the Monitoring Committee of the Ganga Project Authority, I welcome the timely publication of this volume and hope that it will stimulate many more such studies not only on the Ganga but on the other rivers of our country. The value of this programme is not just in terms of the actual study relating to the Ganga, but in stimulating a large number of research scientists and institutions to work on a relevant and exciting problems in their vicinity, giving them new directions and opportunities in research and bringing about the team effort and networking needed to successfully deal with such a complex area. I must place on record our gratitude to Dr. C.R. Krishna Murti for the outstanding contributions he has made in catalyzing and integrating this effort.

MGKMenon

(M.G.K. Menon)

PREFACE

A small, often unnoticed but essential requisite of most Hindu rituals involves a simple invocation to water. The person takes a handful of water and calls upon the Ganga, Yamuna, Saraswati, Godavari, Narmada, Sindhu and Kaveri to manifest themselves in that water. The simple message here is not of religion but of reverence to water – water as precious, water as basic for sustenance of life and water as the symbol of purity.

The reverence for rivers is derived from this basic recognition. However, over the years this tradition of reverence has been severely sullied. The Indian society, in particular the urban society, has become a major pollutor. Cities compete with each other in despoiling the environment. Cities which grew and prospered on the banks of rivers have turned their backs on them and made the once golden streams into putrid drains.

The Ganga Action Plan is a bold and challenging initiative to reverse this sad state of affairs. The thrust of the programme is not on marketing the Ganga. That has been done long long ago and the river is firmly enshrined in the hearts of our people. The main objective is to re-emphasize the simple truth that even now what has been lost can be recovered and the river rid of its pollution. If this can be done in the case of the Ganga, chances are, it can be done for other rivers as well.

Even before the formal launching of the Ganga Action Plan a major effort was initiated to get a better understanding of the river. A multi-disciplinary research programme involving several Universities located on the banks of the Ganga, from Garhwal to Calcutta, was formulated under the guidance of Dr M.S. Swaminathan and Prof M.G.K. Menon. The research programme comprised over 40 different studies with a common physico-chemical assessment as base and covering various items such as biological profile, fungi, macrophytes, riparian vegetation, fish and other aquatic population etc. This integrated research programme is one of the largest ever undertaken in the country. Several hundred scientists ~~have~~ been involved in the programme. A Steering Group under the Chairmanship of Dr C.R. Krishna Murti with Dr R.P. Mathur, Dr K.S. Bilgrami and Dr T.M. Das has been monitoring and reviewing the studies.

Thanks to the strenuous effort of this Steering Group and the cooperation received from the various investigators, it has been possible to bring out the present study. This is probably the first time that an integrated profile of a major river in the country is available. I am sure the study will be of considerable interest to scholars and all others who are interested in the conservation of natural resources in this as well as other countries.

New Delhi
Dated 2nd January, 1989

K. C. SIVARAMAKRISHNAN
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Vice-Chancellors, Principal Investigators, Research Scholars, Technicians and supporting staff of the 14 participating Universities viz: University of Garhwal, Gurukul Kangri Viswavidyalaya, University of Roorkee, Aligarh Muslim University, Kanpur University, Banaras Hindu University, Patna University, Rajendra Agricultural University, Bhagalpur University, Burdwan University, Bidhan Chandra Krishi Viswavidyalaya, Kalyani University, Jadavpur University and Calcutta University.

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The sudden demise of Dr C.R. Krishna Murti made it necessary to have the help of the Madras Science Foundation to see the manuscript through the press to which it readily agreed. The conclusions drawn from the data presented in this publication are those of the respective authors only. The scientists of the Madras Science Foundation have only undertaken to make the manuscript press ready, read the final proofs and make it fit for final printing. They are not responsible for the views and opinions expressed therein. – MINISTRY OF ENVIRONMENT AND FORESTS

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CONTENTS

Page

FOREWORD ... vii
Prof M.G.K. Menon

PREFACE ... xi
K.C. Sivaramakrishnan

ACKNOWLEDGEMENTS ... xii

CONTRIBUTORS TO THE SCIENTIFIC PROGRAMME ... xiii

LIST OF PRINCIPAL INVESTIGATORS AND CO-INVESTIGATORS ... xvii

1. Genesis of the Integrated University Research Programme on the Ganga ... 1
C.R. Krishna Murti
2. Some Physical Features of the Ganga Basin *C.R. Krishna Murti* ... 6
3. Rivers and their Environmental Significance *C.R. Krishna Murti* ... 10
✓4. Stretches of the Ganga covered in the Study *R.P. Mathur* ... 19
✓5. Sampling Stations for Water Quality Monitoring *R.P. Mathur* ... 21
✓6. Trend of Physico-chemical Characteristics of the Ganga Water ... 27
R.P. Mathur
7. Mathematical Modelling of Water Quality ... 39
Himanshu Joshi and R.P. Mathur
8. Instrumentation for Pollution Monitoring of Hugli Estuary ... 47
P. Som
9. Establishment of a Ganga Research Station in the Campus of Banaras Hindu University *U.K. Choudhary* ... 52
10. Biological Profile of the Ganga: Phytoplankton *S. Sreenivasaprasad* ... 53
11. Biological Profile of the Ganga : Fungi *K.S. Bilgrami* ... 67
12. Biological Profile of the Ganga: Bacteria and Bacteriophages ... 72
K.S. Bilgrami
13. The Pathogenic Bacteria in the Ganga Water Collected from Twelve Sampling Points in Varanasi *I. C. Tiwari and P. C. Sen* ... 78
14. Microbial Population and Bacteriophage Activity in the Ganga Water : An Exploratory Study *M. Sen* ... 79
15. Biological Profile of the Ganga : Zooplankton, Fish, Birds and Other Minor Fauna ... 81
K.S. Bilgrami
16. Possible Food-chain Operative in the Ganga ... 95
K.S. Bilgrami
17. Impact of Flood on Productivity of Diara Land and Vegetation ... 99
K.S. Bilgrami
18. Biomonitoring of Water Quality of the Ganga *K.S. Bilgrami* ... 101
19. Macrophytic, Marginal and Riparian Vegetation of the Ganga ... 107
K.S. Bilgrami
20. Integrated Study of the Ganga Ecosystem between Narora and Kannauj (U.P.) *A. M. Siddiqi* ... 117

CONTENTS

Page

21. River Ganga in the Stretch Between Kalakankar (Pratapgarh) and Phaphamau (Allahabad) : A Comprehensive Study *A. K. Sinha* ... 125
22. Physico-chemical Studies of the Ganga Water at Kanpur (Kannauj to Shuklaganj Sector) *U. K. Pandey* ... 141
23. Biological Studies of the Ganga Ecosystem between Kannauj and Shuklaganj *A. C. Shukla* ... 147
24. An Overview of the Hydrobiological Features of the Ganga in the Stretch Mirzapur to Ballia *B.D. Tripathi* ... 156
25. Community Structure, Biomass Production and Energy Aspects of Aquatic Macrophytes and Soil, Water and Nutrient Conservation of the Ganga *R.S. Ambasht* ... 161
26. Environmental Impact of Irrigation by Canals in Mirzapur - Ballia Stretch of the Ganga *R.C. Tiwari* ... 166
27. Assessment of Pollution Load on the Ganga in the Stretch Bally to Bandel *N.C. Datta* ... 171
28. Some Aspects of the Biogeography of the Ganga *T.M. Das* ... 187
29. Socio-Economic Study of the Stretch from Bally to Bandel *K.G. Bagchi and T.M. Das* ... 194
30. Socio-Economic Study of the Ganga from Rishikesh to Garhmukteshwar *T.M. Das* ... 204

✓ 31. Environmental Awareness of the Problems Related to the Ganga *T.M. Das* ... 205

32. The Scientific Study of the Ganga : Perspectives *C.R. Krishna Murti* ... 207

ANNEXURES

ANNEXURE 1 : Constitution of the Working Group for Coordinated Research Projects in the Ganga Basin ... 211
ANNEXURE 2 : Plan of Action of the Working Group on the Ganga Basin ... 213
ANNEXURE 3 : Working Group for co-ordinanted Research Projects in the Ganga Basin ... 214
ANNEXURE 4 : Brief Background note on the Ganga Basin prepared by the Central Board for Prevention and Control of Water Pollution ... 215
ANNEXURE 5 : A note on Standard Methodology for Analysis of Water Samples of the Ganga ... 218
ANNEXURE 6 : Reconstitution of the Working Group on Integrated Action Oriented Research on the River Ganga ... 221
ANNEXURE 7 : Institutions which Participated in the Study ... 223

LIST OF TABLES

Page

TABLE 3.1 : Discharge, Drainage Area and Particulate Load Carried by Some World Rivers 10

TABLE 3.2 : Overall Global River Fluxes of Important C, N, P and S Species : Flux is Expressed in Mass of the Element 12

TABLE 3.3 : Nutrient Concentration in some Typical Rivers 12

TABLE 3.4 : Evaluation of the Mean River Concentrations and Global Fluxes of P and N 12

TABLE 3.5 : Mean River Concentrations and Fluxes of N and P Transported by Rivers to Ocean 14

TABLE 3.6 : Some Data on Transport of Nitrogen by the Ganga 17

TABLE 5.1 : Details of Sampling Stations 22

TABLE 6.1 : Seasonal values of TDS and TSS between Munger and Farakka 32

TABLE 7.1 : Commonly Used Receiving Water Quality Models 40

TABLE 7.2 : Characteristics of Selected Receiving Water Quality Models 41

TABLE 7.3 : Summary of Differential Equations to be Solved by QUAL -II 44

TABLE 8.1 : Sensors Used for Developing the Instrumentation Complex 47

TABLE 8.2 : Calibration Data 50

TABLE 10.1 : Algae Present in Different Stretches of the River Ganga 55

TABLE 11.1 : Correlation Coefficient between Fungal Density and Physico-chemical Factors 69

TABLE 11.2 : Seasonal Average Density of Fungi at Clean and Polluted Sites of the River Ganga (x 10^3/litre) 70

TABLE 11.3 : Selective Isolation of Fungi on Ligno-cellulosic and Lignaceous Sub-strates from Paper and Pulp Manufacture Waste Water 71

TABLE 12.1 : Bacterial Profile of the Ganga Water at Varanasi 73

TABLE 12.2 : Colony Characteristics and Biochemical Tests of Some Bacteria Identified from the Ganga Water 74

TABLE 12.3 : Correlation - coefficient (r) between Physico-chemical and Bacterial Parameters 75

TABLE 12.4 : Resistance of Isolated Bacterial Cultures to Toxic Metals and Five Clinical Antibiotics 76

TABLE 12.5 : Average Value of Indicator Bacterial Parameters at Sultanganj and Bhagalpur 77

TABLE 14.1 : Lytic Activity of Sintered Glass Filtered Water Samples Indicating the Presence of Bacteriophages 79

TABLE 15.1 : Zooplankton Fauna of the River Ganga 82

LIST OF TABLES

Page

TABLE 15.2 : Systematic List of Fishes Recorded from the River Ganga 87

TABLE 15.3 : List of Aquatic Insects Recorded between Munger and Farakka 90

TABLE 15.4 : Molluscan Fauna of the River Ganga 92

TABLE 15.5 : Vertebrate Biota of the River Ganga 93

TABLE 17.1 : Vegetation of Diara Land 99

TABLE 17.2 : Average Total Net Primary Productivity During Pre Flood and Post Flood 100

TABLE 18.1 : Average Species Diversity of Phytoplankton of Different Sites of the River Ganga 101

TABLE 18.2 : Diversity Index (H) of Benthic Macroinvertebrates 102

TABLE 18.3 : Qualitative and Quantitative Enumeration of Algae of the River Ganga at Sewage Disposal Site of Bhagalpur during 1986 – 1987 104

TABLE 18.4 : Pollution Tolerant / Indicator Species of Zooplankton of the River Ganga at Bhagalpur 105

TABLE 18.5 : List of Algae Recorded in the Ganga at Different Sites from Mirzapur to Ballia 105

TABLE 19.1 : List of the Aquatic Macrophytes and Marginal Plants and those Constituting Riparian Vegetation (the lists prepared by some centres are partial. 'M' refers to such plants which are of medicinal value) 108

TABLE 21.1 : Range of Physico-chemical Characteristics of the Ganga Water between Phaphamau (Western side) and Kare-Manikpur during September 1987 to August 1988 and July 1989 to June 1990 126

TABLE 21.2 : WQI of the Ganga Water between Phaphamau (Allahabad) and Kare-Manikpur (Pratapgarh) 128

TABLE 21.3 : Pesticide Residue in the River Ganga Sediments between Kare-Manikpur and Phaphamau during April and June, 1988 130

TABLE 21.4 : Number of Aquatic Fungi in one ml of the Ganga Water between Kare-Manikpur and Phaphamau 132

TABLE 21.5 : Number of Extra Aquatic Fungi in one ml of the Ganga Water between Kare-Manikpur and Phaphamau 132

TABLE 21.6 : Zooplankton Density of the Ganga River between Kare-Manikpur and Phaphamau from Sept 1987 to July, 1988 (Unit = No/Litre) 134

TABLE 21.7 : Zooplankton Density of the Ganga River between Kare-Manikpur and Phaphamau from Aug. 1989 to April, 1990 134

TABLE 21.8 : Blood Parameters of Five Species of Gangetic Fishes 136

TABLE 21.9 : Calorific Values of Gangetic Animals 138

LIST OF TABLES

Page

TABLE 22.1 : Data regarding Sampling Stations of the River Ganga from Kannauj to Shuklaganj (Kanpur) 142

TABLE 22.2 : Range and Mean Values of Physico-chemical Parameters of the Pure Ganga Water (S_1), Mixture of *Nala* and the Ganga Water (S_2) and Pure *Nala* Water (S_3). (September 1987 to August 1988) 143

TABLE 22.3 : Range and Mean Values of Physico-chemical Parameters of the Pure Ganga Water (S_1), Mixture of *Nala* and the Ganga Water (S_2), and Pure *Nala* Water (S_3) (September 1988 to August 1989) 144

TABLE 23.1 : Total Coliform Bacteria in Flowing Waters at Various Sampling Stations (1988-1989) 148

TABLE 23.2 : Occurrence of Keratinophilic Fungi and Dermatophytes at Different Stations of the Ganga 148

TABLE 24.1 : Phytoplankton Species Recorded from Different Sampling sites from Mirzapur to Ballia from September 1986 to March 1988 158

TABLE 24.2 : Aquatic Macrophytes and Plants Observed on both the Banks of the River Ganga from Mirzapur to Ballia (April 1987 to March 1988) 159

TABLE 25.1 : Peak Biomass Values (July 1987), Productivity and Average Energy Concentration of Vijuriavir and Rajghat, March 1987– March 1988 163

TABLE 25.2 : Water, Soil and Nutrient Losses in Relation to Riparian Macrophytes. Values are Average of 7 Natural Rainfall Intensities (Range 0.33 to 5.19 cm h^{-1}) Readings of Rainy Season 1988 164

TABLE 25.3 : Peak Community Biomass (g m^{-2}) and Productivity (g m^{-2} season $^{-1}$) of Rajghat and Vijuriavir Ghat for Winter (November 1985-86 and February 1986-87) and Summer, (March 1986-87 and June 1986-87) 165

TABLE 26.1 : Details of Different Canals 166

TABLE 26.2 : Physico-chemical Parameters of Canal Water and Tubewell Water 167

TABLE 26.3 : Characteristics of Soils Used 169

TABLE 26.4 : Effect of the Ganga Lift Canal and Tubewell Irrigation Water on Summer Moong (green gram). Data Based on Two Year Experiments (Values are per pot) 169

TABLE 26.5 : Effect of the Ganga Lift Canal and Tubewell Irrigation Water on Rice (observations / 5 plants). Data based on Two Year Experiments 169

TABLE 26.6 : Effect of the Ganga Lift Canal and Tubewell Irrigation on Wheat (observations / 5 plants). Data based on Two Year Experiments 170

TABLE 27.1 : Monthly Variations of BOD 171

TABLE 27.2 : Correlation of the Diverse Physico-Chemical Factors 172

TABLE 27.3 : List of Periphyton 176

TABLE 27.4 : List of Phytoplankton 178

LIST OF TABLES

		Page
TABLE 27.5	: List of Macrophytes (Aquatic and Semiaquatic)	179
TABLE 27.6	: List of Zooplankton	180
TABLE 27.7	: Seasonal Abundance of Zooplankton Groups (units / l)	182
TABLE 27.8	: Simple Correlation between the Total Zooplankton and their Major Groups with the Abiotic Parameters	182
TABLE 27.9	: List of Benthic Macroinvertebrates	183
TABLE 28.1	: True Mangrove Species of the Sundarbans Delta	189
TABLE 28.2	: Important Medicinal Plants of the Ganga - Shiwaliks	191
TABLE 29.1	: Nature of Fertilizer Consumption of Two Districts	197
TABLE 29.2	: Crop Production in tonnes/km^2 for Two Districts	197
TABLE 29.3	: Decadal Changing Pattern of the Industries	198
TABLE 29.4	: Nature of Water Supply of the Municipalities	198

ANNEXURE

TABLE 1	: List of Monitoring Stations in the River Ganga	216
TABLE 2	: List of Parameters for Analysis of Water Quality	217
TABLE 3	: Water Quality of the River Ganga (between May, 1980 and March, 1981)	217
TABLE 4	: Scheme for Study of Quality of the River Water	219
TABLE 5	: Analytical Procedures for the River Water (Summary)	220

LIST OF FIGURES

Page

FIGURE 1.1 : Outline of R & D Tasks Related to Water Quality of the Ganga 4
FIGURE 1.2 : Outline of R & D Tasks Related to Hydrobiology of the Ganga 4
FIGURE 2.1 : Major River Basins of India 7
FIGURE 2.2 : The Ganga Basin 8
FIGURE 3.1 : Biogeochemical Cycles in the Dynamics of the Biosphere 14
FIGURE 3.2 : Distribution and Fluxes Between and within Each Sector of Drainage Basin 16
FIGURE 5.1 : The Ganga Stretch : Badrinath to Farakka 23
FIGURE 5.2 : Schematic Diagram of the Ganga River System 24
FIGURE 5.3 : L– Section of the Ganga River (Badrinath to Narora) 25
FIGURE 5.4 : Conceptual Linearised Diagram of the Ganga River (Mirzapur to Farakka) 26
FIGURE 5.5 : L– Section of the Ganga (Mirzapur to Farakka) 26
FIGURE 6.1 : Variation in *p*H 27
FIGURE 6.2 : Variation in Turbidity 28
FIGURE 6.3 : Variation in Total Alkalinity 29
FIGURE 6.4 : Variation in Hardness 30
FIGURE 6.5 : Variation in Chlorides 31
FIGURE 6.6 : Variation in Total Solids 33
FIGURE 6.7 : Variation in Dissolved Oxygen 33
FIGURE 6.8 : Spatial Variation of per cent D.O. Saturation 34
FIGURE 6.9 : Profiles of BOD Variation 35
FIGURE 6.10 : Variation in COD 36
FIGURE 6.11 : A – F : Pristine Ranges 37
: G – J : Pristine Ranges 38
FIGURE 7.1 : Major Constituent Interactions (*Source* : Roesner, L.A., *et al.*, 1977) 42
FIGURE 7.2 A Schematic Diagram of a Hypothetical Stream System (*Source* ; User's manual for stream quality model, QUAL-II, EPA) 42
FIGURE 7.3 : Discretized Stream System (*Source* : Roesner, L. A., *et al.*, 1977) 43
FIGURE 7.4 : General Structure of QUAL-II (*Source* : Roesner, L.A., *et al.*, 1977) 43
FIGURE 8.1 : Probe in General (Protection of cell) 48
FIGURE 8.2 : Thermistor Probe 48
FIGURE 8.3 : Transmitting and Receiving Sides 50
FIGURE 10.1 Monthly Variation in Phytoplankton Density at Bhagalpur (May 1985 to April 1987) 54
FIGURE 10.2 : Some Common Algae of the River Ganga 64
FIGURE 10.3 : Some Common Algae of the River Ganga 65
FIGURE 10.4 : Pollution Sensitive Algae of the River Ganga 66
FIGURE 10.5 : Pollution Tolerant Algae of the River Ganga 66
FIGURE 11.1 : Some Common Fungi of the River Ganga 68
FIGURE 12.1 : Monthly Variation in Bacterial Population at Bhagalpur (May 1985 to April 1987) 75
FIGURE 15.1 : Monthly Variation in Zooplankton Concentration – Bhagalpur (May 1985 to April 1987) 84

LIST OF FIGURES

Page

FIGURE 15.2 : Some Common Zooplankton of the River Ganga 85
FIGURE 16.1 : Food Items of *Daphnia carinata* 95
FIGURE 16.2 : Food Items of *Macrobrachium* 96
FIGURE 16.3 : Food Items of *Rhinomugl corsula* 97
FIGURE 16.4 : Food Items of *Catla catla* 97
FIGURE 16.5 : Food-Web in the Ganga River 98
FIGURE 17.1 : Net Primary Production in Natural and Cultivated Fields of Diara Land 100
FIGURE 21.1 : Map of Stretch of the River Ganga between Kalakankar and Phaphamau 128
FIGURE 22.1 : The Ganga River from Kannauj to Shuklaganj (Kanpur) 145
FIGURE 25.1 : Location of Study Sites 162
FIGURE 26.1 : Location of Canal Lift Irrigation 167
FIGURE 26.2 : Salinity Hazard 168
FIGURE 27.1 : Field Stations : 1–5 + 173
FIGURE 27.2a: Data Summary of the Abiotic Parameters (Stations. 1–5) 174
FIGURE 27.2b : Data Summary of the Abiotic Parameters (Stations : 1–5) 175
FIGURE 27.2c : Data Summary of the Abiotic Parameters (Stations : 1–5) 177
FIGURE 27.3 : Percentage Abundance of three Dominant Phytoplanktonic Groups 181
FIGURE 27.4 : Monthly Variations of Zooplankton 184
FIGURE 29.1 : Changing Pattern of Land use of the Study Area (Data were taken in 1960–61, 1970–71 and 1980–81) 196
FIGURE 29.2 Decadal Growth of Density of Population of the Urban and Rural Police Stations Indicating the rapid Increase of Domestic Load in this Small Stretch 199
FIGURE 29.3 : Nature of water supply in the Ganga Basin (1980–81) 200
FIGURE 29.4 : Death due to Different Diseases (1980) 202

LIST OF PLATES

Facing Page

PLATE 1 (a) . Contour of the Riverine Systems 6
PLATE 1 (b) : The Satellite Image of Gangetic Delta with Hugli River and Indian Sundarban 6
PLATE 2 (a) : The Gomukh – the Traditional Snow Cave for Source of the Ganga 20
PLATE 2 (b) . The Ganga at Varanasi, the Water is Constantly Polluted by Washing of Clothes 20
PLATE 3 (a) : *Anabaena circularis* – A Pollution Sensitive Alga 66
PLATE 3 (b) *Euglena acus* – Indicator of Organic Pollution 66
PLATE 4 (a) A Typical Scene of Tidal Forest Sundarban with Mangrove Species *Nipa fruticans* 188
PLATE 4 (b) · A Typical Scene of Tidal Forest Sundarban with Mangrove Plant Species 188

1

Genesis of the Integrated University Research Programme on the Ganga

C. R. KRISHNA MURTI

The Planning Commission, Government of India recommended Ecosystem Development as a thrust area for the Sixth Five Year Plan (1980–1985). The implementation of the relevant programmes envisaged the participation of the University System to be supported with adequate inputs from the science (University and Eco-Development, Planning Commission, Government of India, New Delhi, March, 1982) and technology sector. A brain-storming meeting was convened by the Science and Technology Division of the Planning Commission on December 21, 1981 to identify areas of research related to Eco-Development. This was attended by Vice Chancellors and Senior Faculty Members of most of the Universities located on the Ganga Basin, academicians, scientists from national laboratories, governmental and non-governmental agencies. A multi-disciplinary study of the Ganga emerged as a priority item of Eco-Development as an outcome of this initiative of the Planning Commission. The need was realised to conduct coordinated research on the following aspects of the Ganga :

(i) the source and nature of pollution;

(ii) a more rational planning of the resources of the Ganga for agriculture, animal husbandry, fisheries, forests ;

(iii) demographic, cultural and human settlements on the banks of the Ganga ; and

(iv) possible revival of the inland water transport facilities using the Ganga, her tributaries and distributaries.

A three-tier model was proposed to carry out the study :

(a) interdisciplinary programme in the participating Universities, national laboratories and research Institutions;

(b) suitable clusters of Universities to work together on problems identified by mutual discussion of the priority areas in their region ; and

(c) all participating Universities working together in an integrated manner with a suitable system for the coordination, monitoring and evaluation of the results of the study.

Working Group on the Ganga Basin

The implementation of the Eco-Development programme on the Ganga Basin was assigned in 1982 to the Department of Environment, Government of India. In order to plan and coordinate the relevant activities, the Department, in turn, set up a Working Group (Annexure 1). A background note prepared by the Secretariat of the Department of Environment was circulated to the members of the Working Group (Annexure 2). The first meeting of the Working Group on Ganga Basin was held on December 31, 1982 in the Bikaner House, New Delhi. Another note outlining the work in progress on the pollution aspects of Ganga under the supervision of the Central Board for Prevention and Control of Water Pollution (CBPCWP) (Annexure 3) was placed on the Table at the time of the meeting. These background papers helped in focussing attention on specific problems needing further investigations.

The work carried out earlier under the aegis of the Central Board for Prevention and Control of Water Pollution (CBPCWP) revealed that pollution of the Ganga had not assumed serious proportions. However, downstream Kanpur and Diamond Harbour were highly polluted and downstream Kannauj, downstream Allahabad and downstream Varanasi were moderately polluted. Surprisingly at Dalmau to the east of Kanpur and the upstream of Allahabad there was very little pollution. Similarly after a spurt at Varanasi there was little pollution at Ghazipur and upstream Patna.

According to the decision taken at the first meeting of the Working Group, the Chairman addressed letters to Vice Chancellors of the Universities who had earlier agreed to participate in the programme. They were requested to suggest dates for visits of the Working Group and the joint enunciation of meaningful research programmes. There was enthusiastic response to this appeal from most of the Vice Chancellors. Subsequently, meetings were organized in the Bikaner House where members of the Working Group had opportunities of discussing the modalities of implementing the programme with the Vice Chancellors or their representatives.

Following extensive discussions on projects prepared by the Universities, the aims and objectives of Phase 1 of the coordinated programme were narrowed down to the following:

(i) assessment of the existing status of the quality of water of the Ganga at different points using defined parameters and internationally accepted analytical methods;

(ii) evaluation of the role, if any, of the fauna and flora of the Ganga in the self-purification reportedly occurring some distance downstream from points of local pollution;

(iii) exploration of the extent of environmental degradation occurring on the banks and the contiguous basin area due to developmental activities and devising of remedial strategies;

(iv) generation of expertise to deal with the complex problems posed by the interaction of pollutants with the biotic and abiotic systems in the Ganga in particular, and the riverine systems of the country, in general, and to monitor and maintain the health of the ecosystems associated with the major river basins of our country.

It became evident that in order to accomplish the above objectives, there was an urgent need within the University systems to reorient their R&D goals, augment the requisite instrumentation infrastructure and, above all, create the right academic environment to sustain the rapid emergence of the identified multi-disciplinary integrated R&D activities and meaningful student participation in the field action component, if any.

Modus of Enunciation and Implementation of the Programme

After consultative meetings with Vice Chancellors and their representatives, the Working Group on Ganga Basin Eco-Development constituted a panel consisting of Dr C.R. Krishna Murti (Chairman), Dr Nilay Chaudhury, Chairman, CBPCWP, Dr N.L. Ramanathan, Department of Environment (Convenor - (Deceased on October 12, 1983), Shri M. Parabrahmam, Department of Environment, and Shri K.V. Mahalingam, Department of Environment to visit University centres in the upper tract (Gangotri-Narora), middle tract (Narora-Patna) and the lower tract (Patna-Hugli) and discuss with participating

The Integrated Programme on the Ganga Includes Study of :

- Physico-chemical and biotic features of the river in relation to water quality.
- Nutrient processing and cycling of the biogeochemical elements Carbon, Nitrogen, Phosphorus and some heavy metals.
- Hydrobiological features including macrophytes of the banks.
- Impact of pollution on the quality of water and biotic characteristics and self-purification.

Projected Short-term Gains of the Programme are :

- Generation of reliable data on water quality for establishing continuous monitoring programme.
- Generation of reliable data on the fauna and flora of the river.
- Identification of problems for a viable Action Plan.

Projected Long-term Gains of the Programme are :

- Building a strong R & D base for Action Plan.
- Developing human resources for undertaking multi-disciplinary studies on rivers.

scientists details of the investigation, methods and logistics. It was agreed that Phase 1 of the studies would assess existing levels of pollution, explore causes for self-purification and regeneration and environmental degradation. Besides this, it was agreed that in each cluster one or more Universities would organize a Workshop to involve the student community for creating public awareness and participating in action programmes oriented towards Eco-Development of the region. The annual fairs and festivals in the main pilgrim centres such as Haridwar, Khurja, Prayag, Varanasi and Sagar were suggested as possible occasions for organizing such awareness campaigns on the health and economic effects of pollution and the need for conservation of the rich resources of the Ganga Basin while maintaining its age-old sanctity.

By the middle of 1983 the panel completed visits to the upper tract and the lower tract and helped the Universities in evolving the coordinated programme and the locale for Workshops for awareness creation. The Department sanctioned the approved coordinated programmes in these two clusters towards the end of 1983.

Irrigation, power generation and transport are the main uses of rivers in India. Equally important are the uses for bathing and for supplying drinking water. If the experience of the 1986 Kumbh Mela at Haridwar is an indicator, the six-yearly or twelve- yearly bathing festivals are likely to attract more and more pilgrims in the years to come. The criteria to be used for defining and determining the quality of the Ganga water have therefore, to be geared to this primary need also. Some of the criteria used for water quality for irrigation and industry can possibly be adapted to suit the requirements of the Ganga as well. There is, nevertheless, a need to include other parameters to testify environmental safety and a minimal adverse impact on the health of the people. It must be remembered in this context that several millions bathe in the Ganga and take home to distant parts of India sealed pots of her water in conformity to an unshakable faith in the sanctity associated with it.

River banks are also used in India for the cremation of the dead and for performing the associated rituals. Varanasi on the banks of the Ganga where it flows from South to North is for the devout the "Maha Smasana", the great cremation ground. Thousands pine to spend their last days in Varanasi, the *Mukti Sthala,* so that they can die there to get eternal liberation. Ashes of those who die at far away places are brought to Varanasi to be mingled with the waters of the Ganga. It will be unrealistic to expect that these age-old customs practised on the banks of the Ganga will vanish overnight. A pragmatic approach would be to determine whether at all these practices do contribute to the pollution load and, if they do, how to minimise it.

A role which the Ganga shares with major Asian rivers is that of transporting the bulk of sediment discharged into the open seas of our earth. Thus, out of the seventy per cent of the total global discharge of particulates contributed to the oceans by Asian rivers, the Indus, the Ganga, the Brahmaputra, the Irrawady, the Salween and the Mekong together account for twenty three per cent. And yet, the major rivers of the South Asian Region, much less the Ganga, have received very little attention from hydrobiologists and specialists in aquatic chemistry and biochemistry. There is a need thus to estimate the annual budget of carbon and minerals of the entire basin, outflow of organic matter and minerals from soil into water, breakdown of litter into smaller fragments by the intervention of biotic activity and the impact of rapid land-use changes on the river banks on the elemental fluxes of carbon, nitrogen and phosphorus. The sediment that accumulates in the flood plains and leaches into the river water plays an important part in the recycling processes. However, no concerted efforts have been made to study the dynamics of these phenomena in the framework of regional biogeochemical budgets or the reported gradual rise of the water basin in the Gangetic plains and its impact on the distribution of trace elements in the soil.

There are also certain distinctive limnological features seen only in the semitropical and tropical rivers. These, presumably, modulate the degradation of litter and, in general, the biological processes mediating self-purification. Aquatic fauna such as turtles and fish and aquatic flora such as algae and fungi and possibly bacteriophages have an implicit role in these processes which has not been elucidated as yet by detailed biochemical investigations. Again, there appears to be some important animals and plants associated with the Ganga which qualify to be considered as species under threat of extinction and, therefore, requiring urgent measures of conservation.

The subject areas for multi-disciplinary studies under this programme include –

(i) physicochemical and biotic features of the river in relation to water quality (Figure 1.1);

(ii) nutrient processing and cycling of carbon, nitrogen, phosphorus and toxic mineral elements ;

(iii) the micro-and macro-flora and fauna, micro and macrophytes, microbes, phages (Figure 1.2);

(iv) impact of organic and inorganic pollutants on the quality of water and on the activity of the biotic community which helps in self-purification.

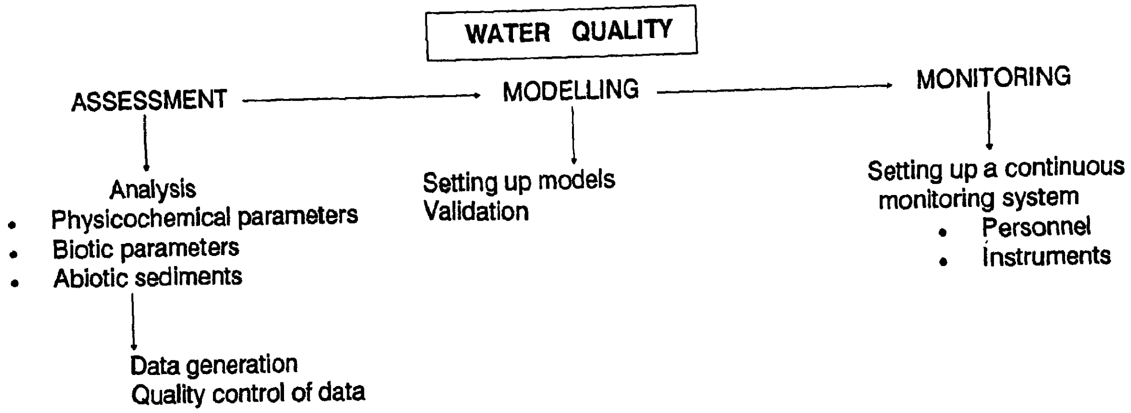
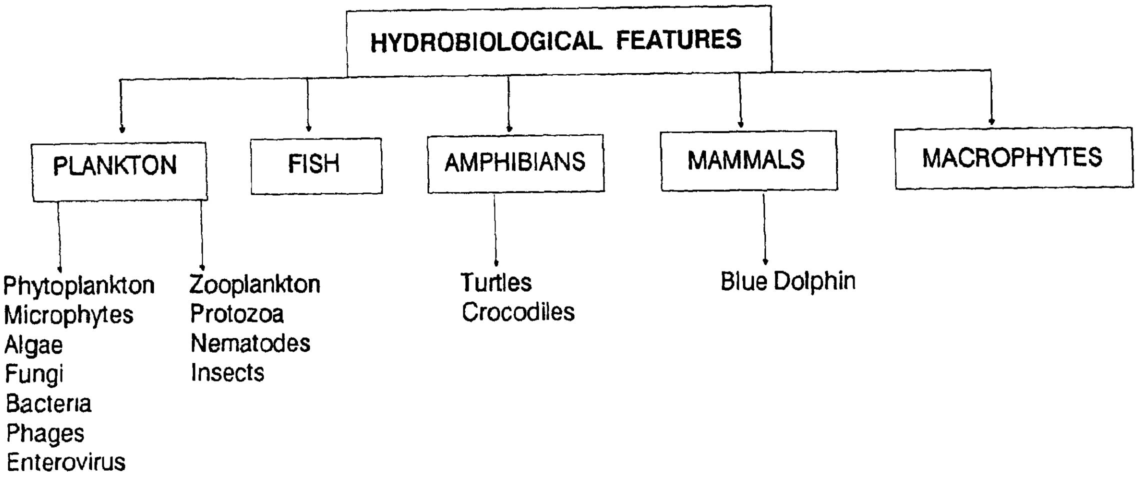


Figure 1.1 : Outline of R & D Tasks Related to Water Quality of the Ganga



Tasks :

Sample Collection and Taxonomical Identification
Identification of Pollution Indicators
Detailed Cellular & Molecular Studies
Identification of Macrophytes for Possible use in Protecting banks

Figure 1.2 : Outline of R & D Tasks Related to Hydrobiology of the Ganga

Fourteen universities located in the Ganga Basin participated in the above programme which were activated in the middle of 1985. The river was divided into five major stretches and each stretch assigned to a group of Universities :

Srinagar to Narora	Garhwal University Gurukul Kangri Viswavidyalaya Roorkee University
Narora to Allahabad	Aligarh Muslim University Kanpur University
Allahabad to Ballia	Banaras Hindu University
Ballia to Farakka	Patna University Rajendra Agricultural University Bhagalpur University
Farakka to Sagar	Burdwan University
The Hugli	Kalyani University Bidhan Chandra Krishi Viswavidyalaya Jadavpur University Calcutta University

The Integrated University Programme on the Ganga aimed to cover :

- Characterisation of the river water in terms of chemical and physical parameters ;
- inventory of macro and micro-flora and fauna of the river ;
- identification of bio-indicators of pollution;
- investigation of the presence and fate of heavy metals;
- microbiological and benthic studies ; and
- carbon, nitrogen and phosphorus budgeting.

Some Highlights of the Programme

Sophisticated analytical techniques (mostly using automated instrumentation) were used for quantifying the physico-chemical parameters of the water quality of the Ganga as part of the Core Programme. Temperature, turbidity, *p*H, electrical conductivity and flow rate, a number of cations and anions, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and dissolved oxygen were measured in several samples drawn from pre-selected points at fixed time intervals before and after the flooding season. The indicators used for health safety were counts of total coliform, faecal coliform, total plate count and enterococci. The work reported in the thirties and forties of this century on bacteriophages was revived deploying more advanced microbiological techniques.

2

Some Physical Features of the Ganga Basin

C. R. KRISHNA MURTI

The main riverine systems of the Indian sub-continent are shown in Figure 2.1, Plate 1 (a). The dominance of the overbearing influence of the Himalayas is evident from the fact that the three major river systems, the Sindhu, the Ganga and the Brahmaputra originate in the lofty heights of the Himalayas. The countries which are co-riparian or share the basin of the Ganga are, India, Nepal and Bangladesh.

Background Information on Ganga

The water of the Ganga has traditionally been regarded as an inexhaustible gift of nature. Rapid development in recent decades of agriculture and industry in the Indian sub-continent have, however, put severe strains on the river and to an extent resulted in some degradation of its quality. Problems of pollution of the water have not only surfaced but begun to assume serious dimensions in certain stretches of the long course of the river.

The investigations conducted hitherto on the Ganga have been restricted in scope and dealt mainly with its hydrological features, flood control and the potential for power generation and agriculture. Very valuable information generated thus is documented in voluminous reports prepared by the Irrigation Commission, Government of India, Ministry of Irrigation and Power (1972) and the Central Water Commission. Other important sources of information are . UN (1966), Rao (1975); Ministry of Irrigation, National Commission of Agriculture (1976); Water Technology Centre (1977); Khosla (1972); Gole and Pattergar (1978); Lal (1981); FAO (1978).

Course of the Ganga

The Ganga rises at 7010 metres in Gangotri, Uttar Kashi district, U.P., India on the southern slopes of the Himalayan Range which forms a natural northern boundary of the Ganga Basin (Figure 2.2). The Yamuna, Ramganga, Gomti, Gandak, Ghaghara, Kosi and Bhagmati are the main tributaries which also originate from the Himalayas. The Hindon the Chambal, the Sind, the Betwa and the Ken feed the Yamuna from the North and South. The Yamuna joins the Ganga from the South at Sangam near Allahabad. Other tributaries joining the Ganga from the South are the Son, Damodar and Rupnarayan all originating from the Vindhyas. With some high plateaus, the Vindhyas mark the southern boundary of the Ganga Basin.

Eleven miles below Farakka in India, the river enters Bangladesh and joins the Brahmaputra at Goalundo. The Meghna joins further south and the combination of the three rivers empty into the Bay of Bengal. From source to outfall, the length covered by the Ganga is about 2,500 km.

Features of the Ganga Basin

The Ganga Basin is one of the most densely populated river basins of the world and as of 1983 sustains in millions 200 in India, 12 in Nepal and 30 in Bangladesh. The total drainage area of the Ganga upto Goalundo is 1,66,834 sq. kilometres of which 1,28,411 sq. kilometres are in India. The vastness of the Ganga basin is reflected in the diversity of its physiography, climate, soils, agricultural development and other related characteristic, Plate 1 (b).

The average annual rainfall over the Ganga Basin varies from 78 cm in the upper part, 104 cm in the middle course and 182 cm in the lower delta of Bangladesh. Most of the rainfall occurs during the South-West monsoon season. Large scale modern irrigation projects have been initiated over the last one hundred years. Irrigation for production of food is the main use of the water. The total cultivable area of the basin is 21,109 sq. kilometres. The cultivable net sown area covering eight States in India is 0.6×10^6 hectares (Rao, 1975).

The present surface water availability in the Ganga basin is about 446 million acre feet (MAF) in India. The total availability of the flow of Ganga at Farakka is in the

PLATE 1 (a)

Contour of the Riverine Systems

PLATE 1 (b)

The Satellite Image of Gangetic Delta with Hugli River and Indian Sundarban

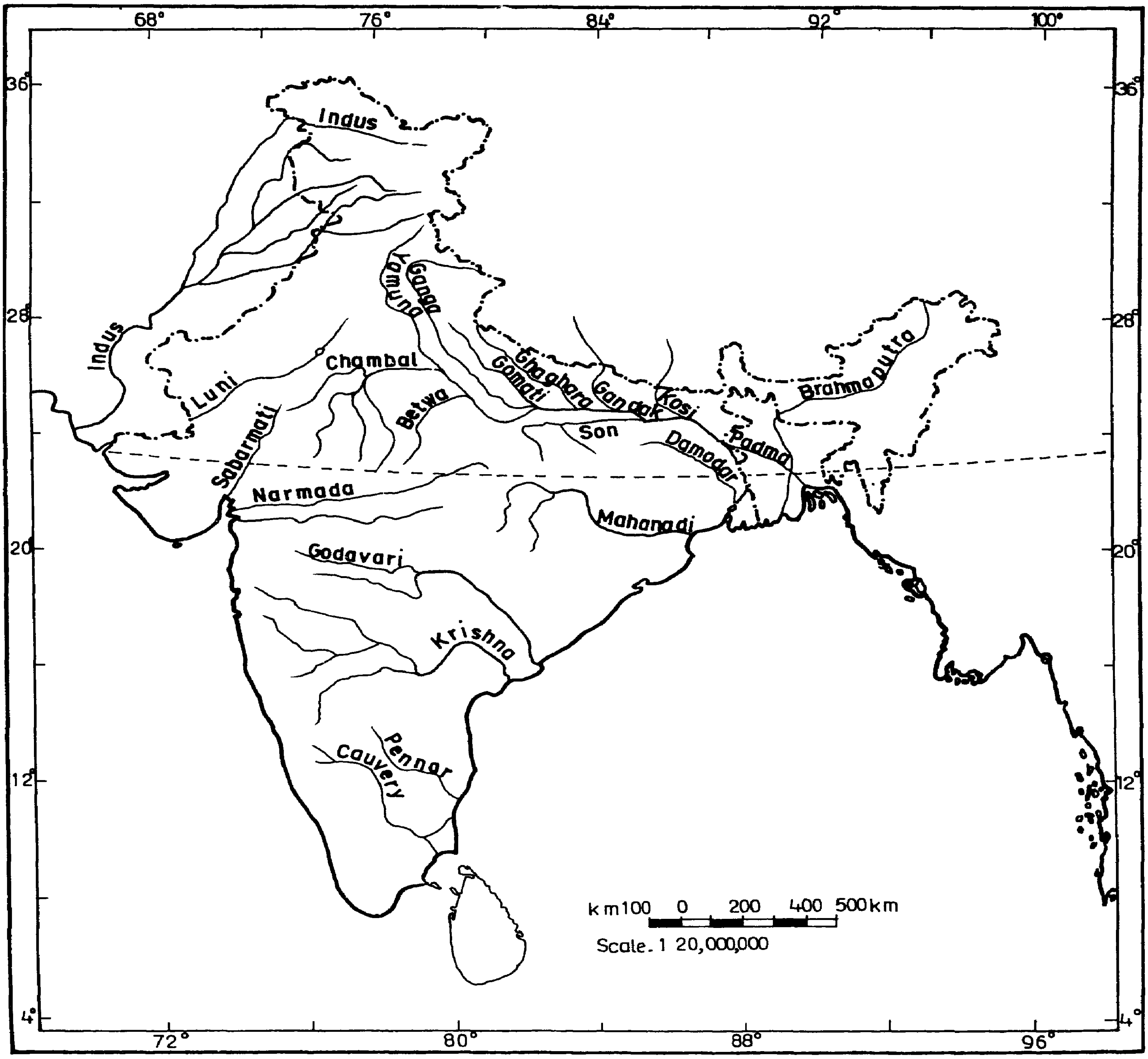


Figure 2.1 : Major River Basins of India

dry season (Nov.–May) 50 MAF and in the wet season (June–Oct.) 322 MAF. The three trans-Himalayan tributaries, the Karnali, Saptgandaki and Saptkosi contribute about 71 per cent of the natural and historic dry-season flows and 41 per cent of the total annual flow of the Ganga.

Broad geological assessment of ground water indicates a potential of 270 MAF in the Basin. The Ganga Basin is the largest and most important watershed in India. The overall development for irrigation covers an area of 18 × 10^6 hectares.The Irrigation Commission of India has estimated that by the year 2,000, requirement of irrigation

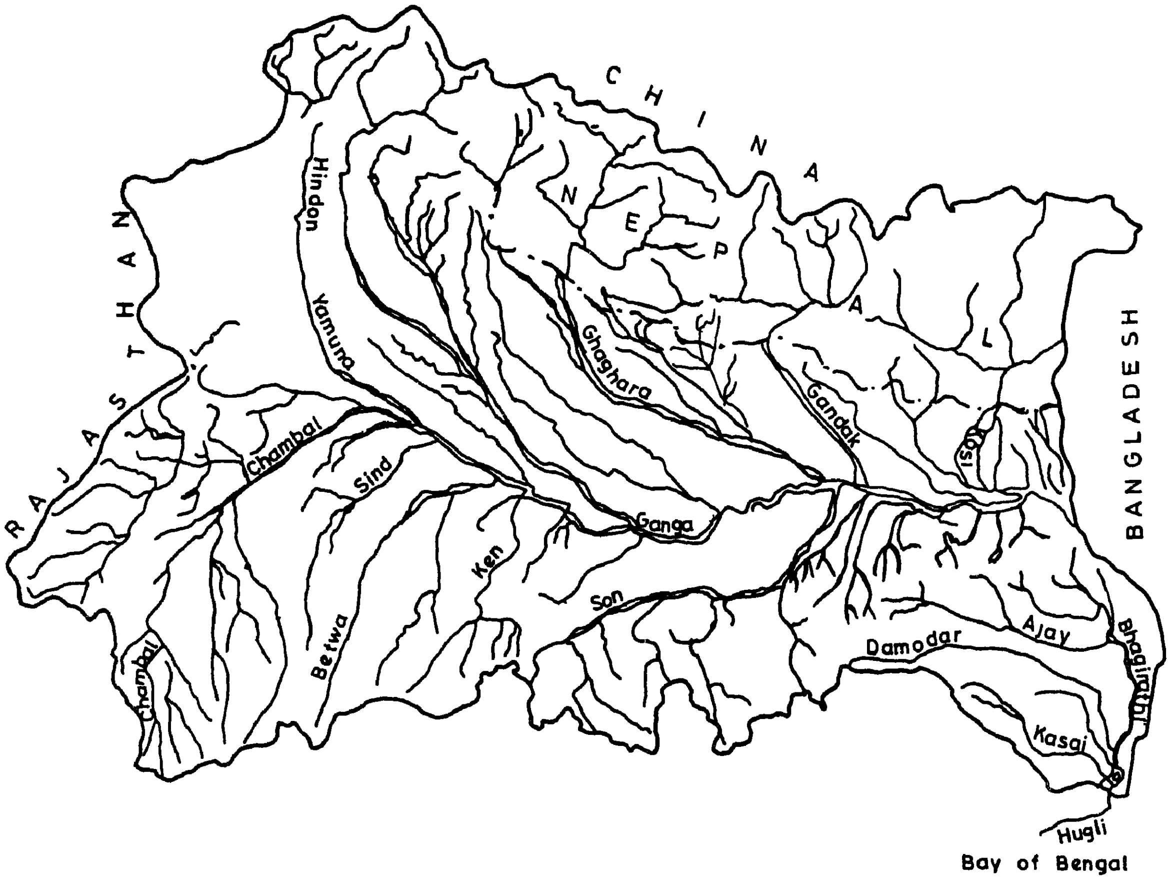


Figure 2.2 : The Ganga Basin

water would be around 150 MAF and for the Calcutta Port alone 30 MAF. The hydro power potential of all river systems originating in the Himalayas, India and Nepal is 28,150 MW at a 60 per cent load factor with the Ganga contributing 11,579 MW out of this estimate (Lal, 1981). There are 52 potential sites for dam construction in the Ganga Basin of which 29 are completed and 23 are proposed ; the total capacity is 54 MAF (Chaudhury and Tauhidual Anwar Khan, 1983).

Isotope Hydrological Study

The International Atomic Energy Agency (IAEA) carried out an isotopic hydrological study of the Ganga in Bangladesh during June 1979 - January 1981. The aim of the project was to assess the environmental isotope content of the river and groundwater, to determine the origin and evaluate the groundwater. Stable environmental isotopes ^{18}O and ^{2}H were analysed in order to determine the origin and behaviour of the groundwater flow. Radioactive Isotopes ^{3}H and ^{14}C (half life ^{3}H =12.43 days ^{14}C = 5,730 years) were used to evaluate the apparent age of the waters. In addition, chemical studies were conducted. The results tend to show that the Ganga has no direct influence on the quality of the groundwater in the region surveyed in Bangladesh. However, the river determines the base level of groundwater (Dray, 1983).

Elemental Recycling in Ganga

The Ganga, the Brahmaputra and their confluence in Bangladesh were sampled for nine months in 1981. Detailed analysis of the samples for sodium, potassium, calcium and magnesium and phosphate, bicarbonate and sulphate and for organic constituents was carried out. Preliminary results suggest that significant quantities of organic carbon are transported by these rivers during the flood periods. Dissolved organic carbon is predominantly derived from flood plain draining. Analyses of the organic carbon give indications of microbial recycling of detritus (Chowdhury *et al.*, 1982).

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3

Rivers and their Environmental Significance

C. R. KRISHNA MURTI

Of all the earth's ecosystems, rivers are the most dynamic having as their primary function the transportation of water. They also carry to the sea the load of the dissolved and particulate output of crustal weathering and erosion from land. Table 3.1 contains figures on the discharge of ten major rivers of the world and the total suspended solids carried by them. What strikes one immediately is the fact that the Ganga, while discharging only 9 per cent of the water output of the Amazon, carries a Total Suspended Solid (TSS) load twice that of the latter. The comparison with Mississippi is also interesting. Whereas the Ganga and the Mississippi have comparable discharge, the TSS carried by the Ganga is five times that of the Mississippi.

Rivers have been studied for many years with inputs from many disciplines of sciences and humanities. Engineering hydrologists, geographers, economists, biologists, chemists, geologists and social scientists have produced a vast body of literature on regional, hydrographical, chemical and historical aspects (Livingstone, 1963; Stumph and Morgan, 1970; Whitton, 1975; Moss 1980; Barnes and Mann, 1980).From data available with UNESCO (1979), UN (1981) on twentynine of the larger rivers of the world, the interannual variance of discharge is found to be between 6 and 33 per cent. Rivers with the highest interannual variation in discharge are those located in the subtropical areas with unstable precipitation conditions. Thus the maximum peak discharge of the Ganga recorded at Hardinge Bridge in Bangladesh touched the 2.5 million cusec mark while the minimum recorded at the same place was only 23,000 cusecs in 1976. The historical average is 65,000 cusecs (Choudhary and Tauhidul Anwar Khan, 1983).

Abiotic and Biotic Processes in Rivers and Estuaries affecting Primary Production

Precipitation, erosion, entrainment from flood plains, chemical weathering, slope run-off and leaching are the main sources for carbon, nitrogen, phosphorus and sulphur in the rivers. The processes are such that the species of these elements are mostly in the oxidized state (CO_2, NO_3, PO_4, SO_4). River composition itself is determined by –

(i) various weathering regimes ;
(ii) the involvement of the flood plains ;
(iii) the character of the vegetation in the drainage basin ;
(iv) hydrographic situations ; and
(v) the occurrence of episodic floods.

Oxidation of the elements to their oxides by aerobic respiration facilitate their easy transport in the dissolved state.

TABLE 3.1

Discharge, Drainage Area and Particulate Load Carried by Some World Rivers

	Discharge $m^3/yr \times 10^{11}$	Drainage Area $m^2 \times 10^{12}$	Total suspended solids $g/yr \times 10^{12}$
Amazon	66.9	6.0	800.0
Brahmaputra	6.3	1.2	800.0
Ganga	5.9	1.3	1600.0
Hoang Ho	1.03	–	2083.0
Indus	2.11	–	616.0
Yangtze	6.9	2.0	552.0
Mississippi	5.8	3.5	309.0
Rhine	0.9	–	0.5
Danube	1.94	–	55.3
Nile	0.90	–	122.0

Data from Degens (1982) and Richey (1983)

The estuarine zone is the scene for the mingling of the waters of the river and the sea. Depending on the hydrodynamical properties of the estuary, chemical and biological processes profoundly alter the transfer of elements. Precipitation, flocculation and sedimentation remove part of the riverborne organic matter and some inorganic species essential for plant growth. Usually the nutrients are in high supply in the estuaries and the decrease in turbidity and consequent better light penetration promote high productivity. The nutrients are then transferred from solution to particulate organic matter and trapped in deeper waters or in sediments. Large amounts of phytoplankton in the photic zone due to high productivity can also cause high turbidities and exert severe limitations on the depth of photosynthetic activity. Increased sedimentation of organic matter can also lead to high biological activity in the benthos.

Organic matter discharged by river and primary production on the surface is degraded by microbial action and the C, N and P compounds resulting from these processes re-enter the overlying waters by diffusion and other phenomena. It is possible that all the oxygen in the sediment is consumed by microbial activity depending on the hydrography of the coastal area. In tropical river estuaries these processes lead to permanent stratification manifest as the mangrove forests.

The coastal zone (marine environment bounded by the 200 metre isobath and the continents) receives the riverine output and produces 25 per cent of the primary productivity of the oceans and recycles 90 per cent of the organic matter that is buried in the ocean floor providing humanity with 50 per cent of marine food. If unpolluted, the dissolved organic matter is mostly exported to the open ocean. Particulate and dissolved organic carbon in the estuary is formed from extensively recycled labile material and hence the vital importance of the biotic component of the estuarine region.

The fluxes of C, N, P, and S induced by excessive human activity have begun to exceed the natural fluxes in many parts of the world. The effects are increased production of organic matter replacing the algae at the base of important food chains with less desirable species, increasing areas of anoxia and added loading of heavy sediments with orgainc carbon (Bolin *et al.*, 1983).

Biotic and abiotic activities of a diverse variety enacted on the stage of land basins are integrated by rivers. They provide media for the operation of the aquatic fluxes of dissolved and particulate organic and inorganic materials. The load carried by the rivers exhibit a wide spectrum of physical and chemical characteristics. These materials enter the rivers through diverse pathways and are utilized, modified and stored by the complex chemistry of inter-phase reactions maintaining a dynamic equilibrium that sustains the living systems in the river basins. The output to the oceans from the rivers is quite different in quantity and quality from the input they receive from catchment areas on the land surface. Considerable variations may occur from one geographical region to another. Above everything, man has over the years changed the nature of many rivers by controlling their floods, constructing large dams and above all abusing them for the dumping of wastes. Few rivers in the world today are "pristine or freeflowing".

Transport of Elements

Rivers have been hitherto considered as 'passive conduits' for the export of terrestrial organic carbon and minerals to the oceans. However, of late, there is increasing evidence to the contrary, although the implicit role of rivers as links in the operation of the cycling of the elements has not been evaluated as fully as achieved for the terrestrial environment (Richey, 1983).

The small temperate rivers of the highly industrialised regions of Europe and North America transport significantly more quantities of nutrients than the world's largest river, the Amazon. Thus the Rhine alone has reached a level almost half of the total load on nitrogenous and phosphatic compounds compared to the Amazon even though it discharges only one hundredth of the Amazon. In terms of the global cycling, rivers export annually to the oceans 800 Tg (10^{12} g)C. This is considerably less than the amount of carbon which enters the rivers. Human activities upstream are estimated to contribute carbon at the rate of about 10-20 per cent of the rate of increase of atmospheric CO_2. Fluxes of other inorganic ions are not precisely worked out but appear to be about 500 Tg annually of dissolved inorganic carbon as carbonates, 200 Tg sulphur annually as sulphate, 11 Tg nitrogen annually (dissolved inorganic N) and 1 Tg phosphorus annually (Phosphate). For N and P alone, the pristine fluxes (before industrialization) were 2 – 5 Tg Nitrogen and 0.5 Tg Phosphorus annually (Tables 3.2, 3.3, & 3.4). Calculations based on modelling suggest that the increased nutrients discharged to the seas stimulate primary production but lead to an increased marine burial rate of the order of 200 – 1000 Tg C annually. The extensive flood plains of rivers accumulate organic matter and nutrients upstream. Due to the intense metabolic activity of riverine ecosystems, it is likely that CO_2, CH_4, NH_3, N_2O and H_2S are produced at some locations causing ecotoxicological damage.

Human activity has drastically modified the transport of nutrients by rivers from land to ocean. According to Wollast (1983), the increase of the dissolved nitrogen flux in rivers represents 30 per cent of the nitrogen fixed annually by man during combustion processes and fertilizer production (6×10^{12} moles yr^{-1}). For phosphorus the increase is only 15 per cent of the total phosphorus mined annually.

Fluxes of C, N, P and S

In all aquatic systems the external input of nutrients is only a small fraction of nutrient uptake because of the rapid turn-over of plankton. Primary production (P) is a function of both the external flux of nutrients (I) and rate of decomposition (D) of the organic matter in the system. At steady state, $P = I(1 + D/I)$ where I is input of nutrients and thus the productivity is very much dependent on decomposition.

Bicarbonate and SO_4^{2-} are among the major dissolved ions in river water with world averages of about 58 mg litre $^{-1}$ and 11 mg litre^{-1} respectively. Nitrate, NH_4^+ and PO_4^{3-} vary from mg litre $^{-1}$ in polluted system to traces in pristine rivers. Sulphate is relatively conservative in its behaviour.

TABLE 3.2

Overall Global River Fluxes of Important C, N, P and S Species : Flux is Expressed in Mass of the Element

Species	Flux ($10^{12} \times g\ yr^{-1}$) Tg yr^{-1}
Total Organic Carbon	800 ± 400
Dissolved Inorganic Carbon	500
Nitrate	11
Phosphate	1
Sulphate	208

From Richey (1983)

Nitrate, NH_4 $^+$and PO_4^{3-} are used along with CO_2 for primary production by macrophytes, periphyton and suspended algae. Respiration, microbial metabolism, action of macro-invertebrates and fish feeding on particulate organic matter account for the regeneration of nitrate, NH_4^{+1}, PO_4^{-3} and CO_2. Depending on the microecosystem, oxidation, nitrification, denitrification, sulphate reduction and fermentation are optional pathways. Inundated flood plains constitute "hot spots" producing methane, ammonia and hydrogen sulphide. Organic C, N, P and S could be stored for considerable

TABLE 3.4

Evaluation of the Mean River Concentrations and Global Fluxes of P and N

	P	N
Pristine concentration (*Co*)		
(μ moles litre^{-1})	0.40	5.00
Pristine flux (moles year^{-1})	15×10^9	180×10^9
Man's perturbation (*a*)		
(mole $inh^{-1} yr^{-1}$)	20.00	500.00
(kg $inh^{-1} yr^{-1}$)	0.19	7.00
Present Day Concentration (*C*)		
(μ moles litre^{-1})	2.00	52.00

From Wollast (1983)

For both total nitrogen and total phosphate there is an increase in concentration as a function of the population density normalized to the water discharge The slope of the curve log *c* versus log inh^{-1} litre^{-1} sec^{-1} increases to 1 suggesting that the concentration of nutrients in a river system can be approximately evaluated from

$$C = Co + ax$$

Where *Co* is concentration of nutrient in pristine water, *a* is rate of production of nutrient per inhabitant and *x* the number of inhabitants per unit of water discharge of the river. (Wollast, 1983)

TABLE 3.3

Nutrient Concentration in Some Typical Rivers

	(μ moles litre $^{-1}$)					
	Phosphate	Nitrate + Nitrite	Ammonia	Total Nitrogen	Silicate	N:P
Amazon	0.4	3.7	–	3.7	187	7.5
Hudson	3.0	50.0	20.0	70.0	70	23.0
Mississippi	2.8	156.0	<4	160.0	83	57.0
Rhine Upper	0.5	30.0	2.5	32.5	61	65.0
Rhine Lower	11.4	230.0	90.0	320.0	90	28.0

From Wollast (1983)

periods within the river system itself. The balance between entrainment, deposition and respiration determines the potential of the flood plains to act as a long-term source or sink of the elements.

Like in an ideal "ecosystem" where materials are recycled, rivers export to the next reach nutrients that are not processed or retained within themselves. Eventually, the riverborne C, N, P and S are transported into the estuary. Organic fractions are refractory after they have been processed within the river. The particulates are sequestered mostly in near coastal sediments (Wollast, 1983). Microbial respiration of the sediments then becomes an important source of nutrients for the water column. Direct regeneration and mobilization from the inorganic phases as a result of redox conditions lead to the production of CH_4, NH_3^+ and H_2S. About 10 – 15 per cent of dissolved carbon can flocculate whereas the rest is exported from the estuaries. After the particulate fractions have settled, the riverborne nutrients stimulate primary production either directly or after being regenerated in the salt wedge.

Substantial changes in speciation can occur in the water column and sediments. There is continuous decrease in the degradation observed with water depth particularly in marine sediments. There is higher percentage of degradation of organic matter within the water column with increasing depth leaving less organic matter for recycling in the benthos at greater depth. The coastal zone is characterized by the main role played by the benthic system. The shallow depth of this zone leads to :

(i) highly reactive organic matter being deposited by sedimentation inducing intense biological activity in benthos

or

(ii) the primary producing zone is in direct contact with the benthic boundary layer becoming an important source of nutrients.

Human Activity and Fluxes

There are many uncertain points in the estimation of natural and present day fluxes of N and P in rivers. However, the contribution due to human activities is several times larger than the natural fluxes. Under the influence of morphological and hydrodynamical characteristics, chemical and biological processes mediating speciation of nutrients and their transfer to the adjacent coastal zone are profoundly altered. The coastal zones are characterized by high biomass and short food webs, high turn-over rates and large transfers of organic matter to the sediments. The increase of N and P discharged by rivers polluted by human activities lead to the modification of the phytoplankton composition of the coastal waters.

Modern river basins can be divided into four classes according to morphological patterns :

(1) those deriving most of material from mountains marginal to the flatlands (Amazon, Mississippi);

(2) those marginal to a fold belt and flow parallel to it (Ganga) ;

(3) tnose which flow along the strike of a mountain chain ; and

(4) those superimposed across mountain chains.

The mouths of most rivers are located along the trailing edges and marginal sea coasts of their respective continents. This leads to the formation of the characteristic sub-aerial and submarine deltas where the riverborne materials may be ultimately buried.

Within each basin, the interplay of precipitation, discharge, basin area and suspended load produces very different patterns. The greatest export of total organic carbon as the sum of dissolved organic carbon and particulate organic carbon is from the sediment rich waters of Asia and the high discharge organic rich rivers of Latin America and tropical Africa.

The Role of Rivers in Biogeochemical Cycling

Products arising out of the weathering of rocks and minerals are transported to the ocean by rivers. The dynamics of such transport is controlled by biogeochemical cycles (Figure 3.1). Dissolved and suspended loads carried by rivers are both structurally and chemically modified by the cycles. Precipitation, erosion, entrainment from flood plains, chemical weathering, slope run-off and leaching are the sources of C, N, P and S in rivers.

Major perturbations in the weathering cycles induced by human activity have resulted in increased fluxes of C, N, P and S throughout the hydrosphere. Increase in N and P leads to a parallel increase in photosynthetic activity. Levels of dissolved inorganic nitrogen and phosphorus in the aquatic environment have over the last 30 years increased by a factor of two. This is apparently due to the wide-spread use of fertilizers, detergents and industrial chemicals containing N and P. In addition, there is increased transport in the weathering cycle of organic carbon due to deforestation and land-use changes. Human activity has drastically enhanced the quantity of nutrients transported by rivers from land to ocean as evident from Table 3.5. The increase in dissolved nitrogen fluxes in rivers represents 30 per cent of the nitrogen fixed annually by man during combustion processes and production of fertilizers (Wollast, 1983).

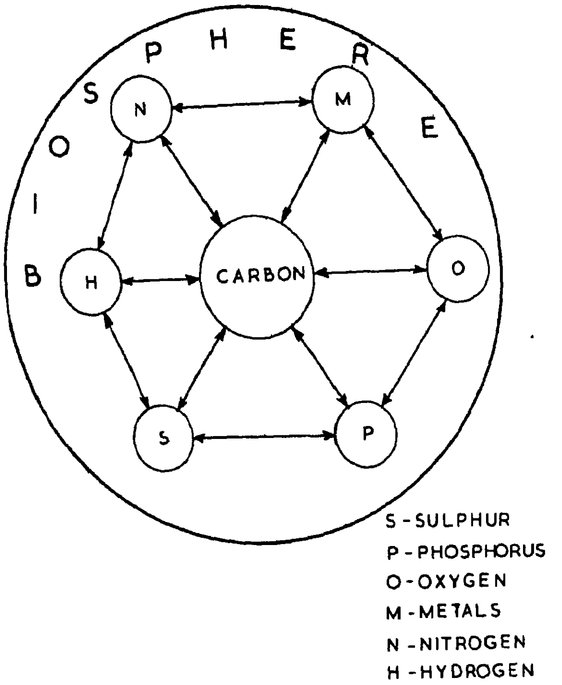

Figure 3.1 : Biogeochemical Cycles in the Dynamics of the Biosphere

The increased biological activity due to the entry of N and P in rivers had led in some cases to anoxia and consequent fish mortalities. Water inpoundment for flood control and hydroelectric power generation or water storage has caused the retention of large amounts of particulate materials. Rivers may also carry elevated levels of toxic metals unfavourable to primary productivity.

Elemental Fluxes

The movement of organic matter and nutrients through a river basin can be viewed as a series of steps down the valley as materials are stored temporarily in tributaries, flood plains and alluvial fans. From the drainage basin, particulate organic matter enters the headwater streams via litterfall, dumping and erosion. Dissolved inorganic carbon is produced by weathering of carbonate and aluminosilicate minerals with atmospheric CO_2, oxidation of soil organic matter and by root respiration. It enters the river through ground water and overland flow as well as gas-exchange. Dissolved organic matter, produced through human decomposition, enters through ground water or overland flow.

Various pathways are employed in the entry of C, N, P and S into a river system. Depending on the *p*H and temperature of soils, NH_4^+ and NO_3^- ions are produced in the watershed through ammonification and nitrification of organic matter and mobilized into rivers through run-offs. The weathering of apatitic rocks is the major natural source of PO_4^{-3}. Rain is a source of dissolved N and S. N, P and S from fertilizer application, sewage and non-point source run-off contribute significant quantities of dissolved species of N, P and S near human habitation.

TABLE 3.5

Mean River Concentrations and Fluxes of N and P Transported by Rivers to Ocean

	N	P
Pristine concentration (Co) μ moles litre^{-1}	5.0	0.4
Present day concentration (C) μ moles litre^{-1}	52.0	2.0
Natural flux (10^{12}g Year $^{-1}$)	5.0	0.5
Contribution of human activity (10^{12} g yr^{-1})	19.0	1.9

A sequence of oxidation-reduction reactions takes place in rivers. Nitrate, NH_4^+ and PO_4^{-3} are taken up along CO_2 during primary production by macrophytes, periphyton and suspended algae. Regeneration of these ions occurs through respiration, microbial metabolism the macro-invertebrates and fish, which graze on particulate organic materials.

There is a direct exchange of particulate matter between the flood plain and the main river through the processes of entrainment and deposition. The rate of change of river stage, peak discharge, channel and flood plain geometry and flood plain vegetation all interact to determine the nature of flood plain deposition and capture dynamics.

An important feature of rivers is that organic C, N, P and S may be stored for considerable periods within the river system itself. Organic carbon and nutrients that are not processed or retained within one sector are exported to the next reach. Eventually the riverborne C, N, P and S are transported into the estuary.

Mass Balance and Distribution

The concentrations of C, N, P and S in the water and sediments at any site in a river are dependent on chemical events that have occurred upstream in the channel, tributaries or in the watershed. Qualitative and quantitative changes in the material load are brought about by specialised biological communities and by physical retention processes. The dynamics of these changes can be accounted for in the format of a mass balance of the respective elements by river sector. Thus, mass continuity equations can be drawn for the fluxes for DIC, DOC and POC in the main channel. Solutions of these equations give the concentration of the respective species.

The "River continuum concept" developed after studies of the temperate North American rivers, enables the prediction of the distribution of ecological events in flowing water with increasing spring order. The energy input and organic matter transport, storage and use by functional feeding groups is regulated largely by fluvial geomorphic processes. The biological organization of rivers has been found to conform structurally and functionally to the kinetic energy dissipation patterns of the physical streams. This facilitates the adjustment of biotic communities rapidly to any change in the redistribution of kinetic energy by the physical system. The above conceptual model, interesting as it is, has not been validated. It is also doubtful whether the model can be applied in its entirety to the Ganga.

One could perhaps begin realistically by collecting sector-wise data for mobilization of POM, DOM, DIC & N, P, S from land to the tributaries and then to the main channel and the exchange of the fluxes with the flood plain. The box model suggested by Richey (1981, 1983) appears to be suitable for this approach (Figure 3.2).

Within each basin, the interplay of precipitation, discharge, basin area and suspended load results in very different patterns for the world's major rivers and their respective geographic regions. The Asian rivers Yangtze, Brahmaputra and Ganga transport a disproportionately large amount of total suspended solids (TSS) reflecting the high erosion rates and the steep relief of the continent. This is an important background feature which must be remembered while constructing the biogeochemical cycles of the Ganga.

Features of the Ganga Relevant to Biogeochemical Cycling

The Integrated Programme on the Ganga was initiated in the middle of 1985. The Universities covering the tract of the river up to Narora and from Varanasi to Sagar have completed the studies. The work on the sector Narora to Kannauj, Kannauj to Shuklaganj (Kanpur) and Shuklaganj to Phaphamau (near Sangam) was also completed towards the end of 1989. Nevertheless, we have information on waterquality parameters on the relatively unpolluted (pristine ?) stretch and the highly polluted terminal stretch of Hugli. Uniform methods have been used for analysis. A note on methodology for water analysis was circulated to all participating laboratories. The note was prepared on the assumption that Universities will be generating data on water quality which could also be used for sector-wise compilation of the fluxes of C, N, P and S. The methodology suggested was based on the SCOPE International Project on Carbon in Global Rivers operating at the University of Hamburg, Germany. It is thus possible to make tentative estimates of pristine (Gangotri to Srinagar stretch) and present levels of Carbon, Nitrogen, Phosphorus and Sulphur and their fluxes in the different sectors.

It is known that the greatest export of total organic carbon to oceans by river fluxes is from the sediment - rich waters of Asia. Uncertainties in the actual discharge are due to the unreliability of measurements of total suspended solids (TSS). The ratio of TOC : TSS for Asian rivers based on reliable data has not been determined with precision. Unpublished data on POC values in the tributaries of the Ganga are reported to be as high as 100 mg litre^{-1} and POC : TSS ratio of 0.2 to 0.4 per cent.

It is unlikely that the data generated in the present phase of the Integrated Research Programme will be adequate to make realistic estimates of the fluxes of the biogeochemical elements. Increased human activity on the banks of the Ganga and extensive fertilizer application have led to significant increments in the export of N and P to the Bay of Bengal. The potential for increased marine primary production has been considerably augmented. The existing data on export of nutrients to the oceans is mostly derived from studies on rivers located in the temperate zones of Europe and North America. Very few systematic studies have been conducted on the nutrient transport by the major rivers of Asia and Africa (Degens, 1982). Under a major project on Biogeochemical cycles of rivers sponsored by SCOPE/UNEP, some preliminary data on particulate and dissolved amino acids and amino sugars, amino acid N, and amino sugar N and discharge of organic N load of the Ganga has been published. (Table 3.6) (Ittekot, Martins ane Seifert, 1983).

Some data on Dissolved Organic Carbon is also available for samples of the Ganga collected in Bangladesh in 1981-82 under the SCOPE study (Choudhury *et al*., 1982). The distribution of dissolved organic carbon (DOC) shows a maximum value of 9.4 and a minimum of 1.4 mg C/l. The concentration of carbohydrates varied from 138.4 and 1119.2 μg/l. Dissolved amino acids vary between 157 and 638 μg/l. Variations of non-protein amino acids such as β–alanine and γ-amino butyric acid indicate active microbial recycling on the flood plains.

The data presented in the SCOPE report is based on analysis of random samples of water of the Ganga collected from Bangladesh. Similar budgeting of carbon

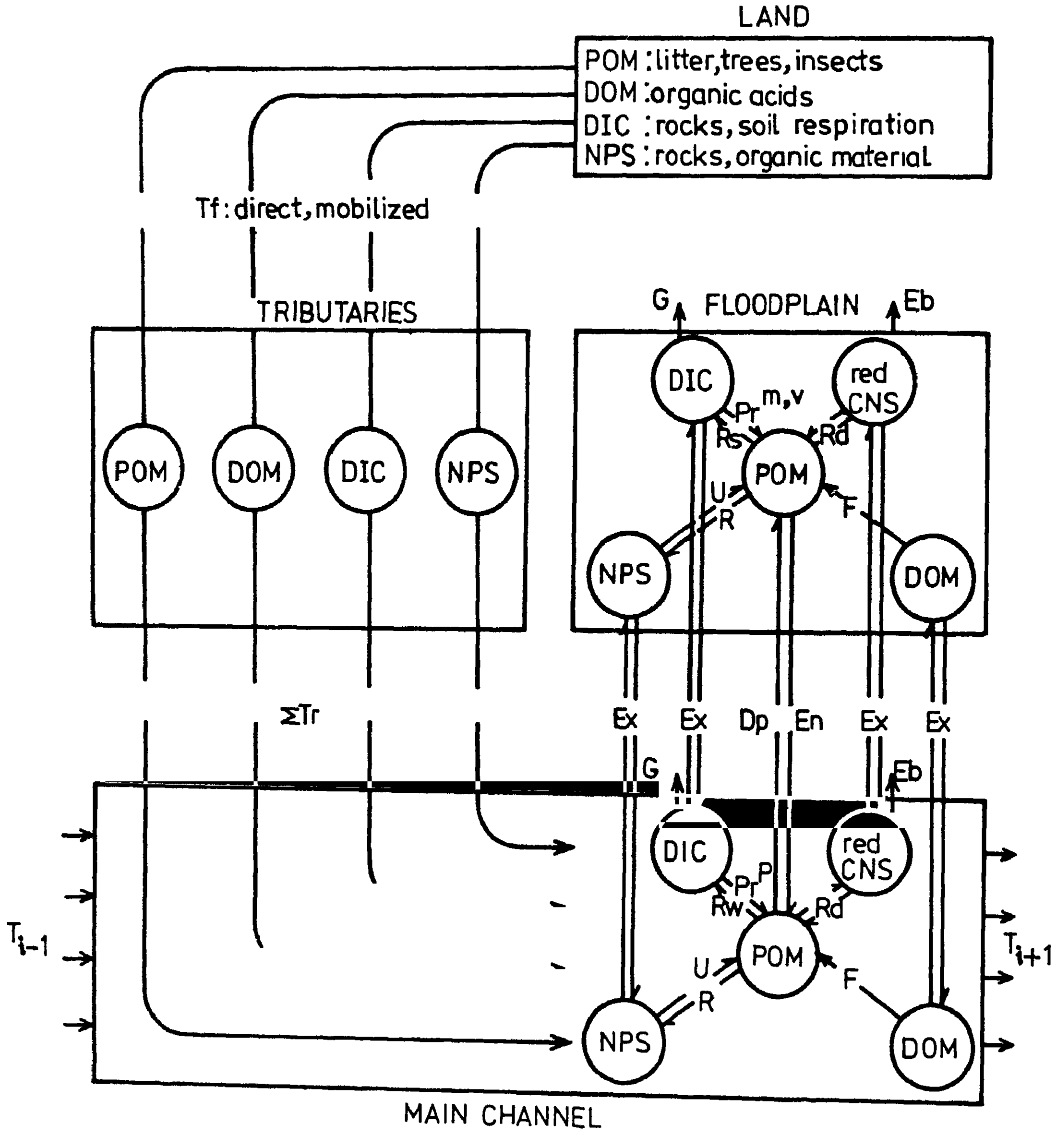

Figure 3.2 : Distribution and Fluxes Between and within Each Sector of Drainage Basin

POM = Particulate Organic Matter
DOM = Dissolved Organic Matter
DIC = Dissolved Inorganic Carbon
NPS = Dissolved Inorganic N, P and S
red CNS = Reduced species of C, N and S

For each sector i, transport pathways include terrestrial inputs to tributaries via direct (litterfall) or mobilized (Ground water erosion) routes T_f

Total tributary inputs to the main channel are (ΣT_r)

Ti – 1 = is import from upriver sector
Ti + 1 = is export to downriver sector
P_r^P = Primary production by phytoplankton

P_r^m = Primary production by macrophytes
P_r^v = Primary production by vegetation in contact with water
R_w = Seston respiration in the water column
R_s = Floodplain sediment respiration
E_n = Entrainment
D_p = Deposition and sedimentation
R_d = Reduction and Oxidation
U = Nutrient Uptake
R = Regeneration
F = Flocculation
E_x = Exchange
G = Gas evasion
E_b = Ebullition

and phosphorus is yet to be done. The dense human population inhabiting the Ganga Basin can profoundly affect the carbon flux by contributing to organic carbon through biological wastes. Similarly the extensive use of the water by a network of irrigation canals coupled with an increasing application rate of nitrogenous and phosphatic fertilizers could add to the fluxes of N and P.

Initiation of any project on compilation of fluxes of C, N, P and S has to cover the entire basin. Samples for analysis will have to be collected from the tributaries and the main stream and the distributaries for a period of at least one year. The sampling points will be at confluence points of streams of first order or second order and the confluence points of the main tributaries with the river. Monthly samples will be collected and analysed for the parameters that will be necessary for calculating the fluxes of C, N, P and S in that order.

TABLE 3.6

Some Data on Transport of Nitrogen by the Ganga

Particulate Amino Acids	1724.0	(μg/l)
Particulate Amino Sugars	193.0	(μg/l)
Dissolved Amino Acids	440.0	(μg/l)
Dissolved Amino Sugars	13.0	(μg/l)
Particulate Aminoacid Nitrogen	252.0	(μg/l)
Particulate Aminosugar Nitrogen	13.5	(μg/l)
Dissolved Aminoacid Nitrogen	134.6	(μg/l)
Dissolved Aminosugar Nitrogen	0.9	(μg/l)
Discharge of River	588.0	(km^3 yr^{-1})
Particulate Nitrogen Load	156.0 × 10^3	(t yr^{-1})
Dissolved Nitrogen Load	37.5 × 10^3	(t yr^{-1})

Based on Ittikot et al., (*1983*)

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4

Stretches of the Ganga covered in the Study

R. P. MATHUR

The river Ganga occupies a unique position in the ethos of the people of India. Emotional attachment to the river and to the centres of pilgrimage on its banks runs deep and long into Indian history. Ganga originates at Gomukh [Plate 2 (a)] at a height of 7010 metres above the mean sea level, traverses a length of 250 km on Himalayan ranges before entering the plains. Emerging as Alakananda, from an ice glacier beyond the Mana pass, 8 km away from the pilgrimage centre Badrinath, the Ganga courses its way to the Bay of Bengal covering a distance of ca. 2525 km through U.P., Bihar and West Bengal. During its long course it embraces many small torrents and tributaries of varied origin. The Ganga follows the ghatline and on the extreme west separates the sources of the Jadhganga, one of the headwaters of Bhagirathi from the Hopgadh, in its turn an affluent of the Sutlej.

First to join Alakananda on its long journey is Dhauli at Vishnuprayag. The combined stream flows south west to the Chamoli region receiving at Birahi the Rudra Ganga, Patal Ganga and Birahi Ganga. Then flowing in the southernly direction to Nandaprayag, it joins Nandakini coming from the east. It turns south west again to Karnprayag, 72 km from Vishnuprayag where it joins Pinder from the Kumaon Himalayas. The stream then flows westward and receives the river Mandakini from the north at Rudraprayag. Turning south-west it flows by Srinagar to Devprayag, 59.2 km downstream, to receive its biggest tributary, the Bhagirathi. There is a common belief that this is the real GANGAJI that emanates from the Gomukh glacier. The united stream, now known as Ganga, flows and ends its roaring journey across the hills and breaks through the Shiwalik range near Rishikesh to enter the plains.

The first man-made project for exploitation of the water of the river has been set up at Rishikesh. Here the waters of Ganga, barring a narrow stream, is diverted to the Chilla Canal for power generation leaving only a 12 km stretch with very thin flow. Subsequently, however, it gets replenished by Song at Satyanarayana (17 km downstream of Rishikesh) and Suswa (3 km down of Song confluence). The tail waters of the Chilla power channel rejoin the mainstream above the Bhimgauda barrage and supplement the flow. The off take channel at this barrage diverts its water into the Upper Ganga Canal reducing it to a slim thread. The next major headworks is located at Bijnor, about 73 km from Haridwar, where the river is again intercepted and an appreciable part of the flow is diverted to the Madhya Ganga Canal. Further downstream the water from the Ramganga feeder meets the Ganga at Tigri (90 km from Bijnor) and provide some relief. The river is once again intercepted at Narora about 82 km from Garhmukteshwar, where the headworks facilitate in diverting an appreciable flow into the Lower Ganga Canal.

From Haridwar downstream, the river is fed by Ramganga at Farakkabad, the Yamuna at Allahabad and the united stream moves towards Varanasi, Plate 2 (b). Downstream of Varanasi, the Varuna joins the Ganga on the left bank at Khalispur. The river then flows to Ghazipur, where it joins the united stream of its two major tributaries, the Sai and the Gomti. Further downstream of the Gomti confluence, the Ganga receives the Basu Nadi on the left and the Karamnasa on the right bank at Narbatpur. Before reaching Buxar, Ganga is joined by the Thora on the right bank. It then enters Bihar passing through Ballia. At the U.P. – Bihar border the Ghagra which is formed by the confluence of Sarda, Sarju, Gori and Kali joins the Ganga on the left bank. In Bihar, the Ganga receives the Sone, the Gandak and the Punpun. The Gandak, which originates from Nepal and is formed by seven holy Gandakis join the Ganga on the left bank at Hazipur. After passing through Patna it receives waters from the Patna canal and the combined stream of the Punpun, the Morhan, and the Dordha at Fatuha and moves to Munger. The united stream of the Harohar, the Dhanayan, the Mohani, and the Dharhara Nadi join on the right bank and the Barhi Gandak on the left bank. Then on its way to Bhagalpur, the Ganga receives the Man Nadi and the Jumania Nadi on the right bank. Downstream of Bhagalpur, the Kosi joins Ganga at Kursela on the right bank. The river now enters West Bengal. At the Bihar–West Bengal border the Gomti joins on the right bank of Ganga.

Downstream to Farakka barrage the Mor, the Ajay, and the Kunar meet on the right bank and the Bhagirathi on the left bank. Then the Ganga passes through Calcutta as the Hugli river and taking the waters of the Damodar, the Rupnarayan and the Haldi rivers it reaches its destination, Sagar.

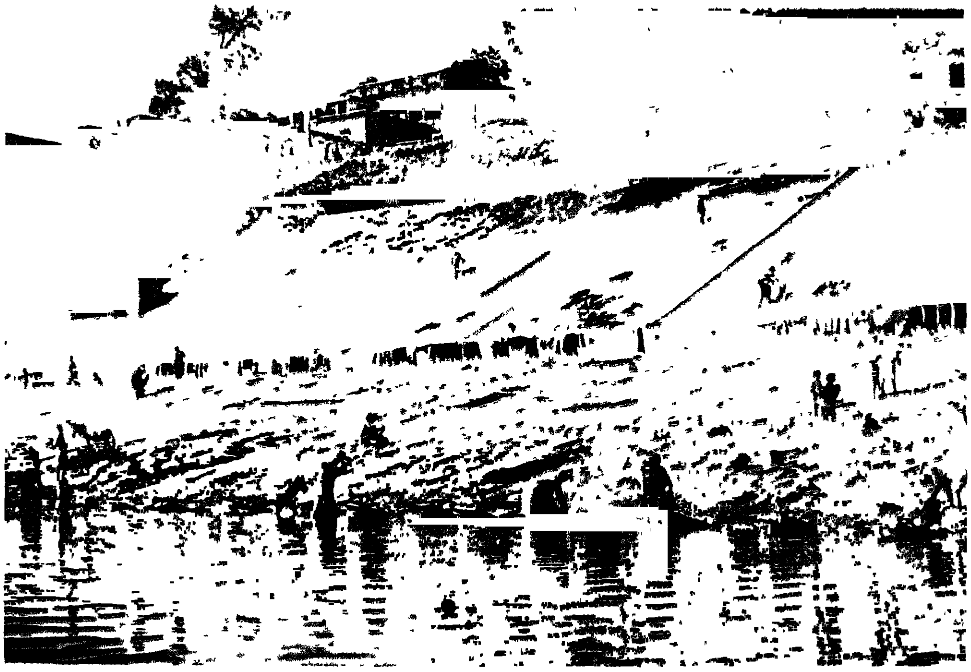
The entire stretch of the Ganga can be divided into three reaches viz. UPPER REACH, MIDDLE REACH and LOWER REACH.

UPPER REACH – Origin to Narora
MIDDLE REACH – Narora to Ballia
LOWER REACH – Ballia to Farakka.

PLATE 2 (a)

The Gomukh – the Traditional Snow Cave for Source of the Ganga

PLATE 2 (b)



The Ganga at Varanasi – the Water is Constantly Polluted by Washing of Clothes

5

Sampling Stations for Water Quality Monitoring

R. P. MATHUR

Studies undertaken by various Universities involved sampling and monitoring at many stations. Results of twenty eight important stations are represented here covering a stretch of 1923.2 km from Badrinath to Farakka and are dealt with comprehensively. The selection was based on considerations of maximum representativeness of samples and approachability from logistics of collection. Details of the sampling spots are given in Table 5.1 and Figures 5.1, 5.2, 5.3, 5.4 and 5.5. The details of the middle stretch are also included in this volume*.

1. **Badrinath** : The first sampling station adjacent to the source of the river is situated 8 km down of Mana at an elevation of 3086 metres. In the winter it remains covered with snow. Only from May to the first half of November it is accessible for sampling. This period is utilized by a large number of pilgrims and bathing activity becomes intense.

There are hot springs known as 'Tapta Kunda' where the devotees have a dip before entering the temple for offering. The effluents from 'Tapta Kunda' finally meet the river downstream.

2. **Nandprayag** : Situated 71.9 km downstream of Badrinath at an elevation of 880 metres, is the meeting point of the tributary Mandakini with the Alaknanda. It is surrounded by a very small hill town Nandaprayag with few educational institutions, dispensary and rest houses. Bathing activities and domestic discharges are not significant.

3. **Rudraprayag** : Situated at an elevation of 725 metres and 47 km downstream of Nandaprayag, it is the confluence place of the Mandakini flowing from Kedarnath. This small town is always crowded with tourists and pilgrims bound to Badrinath and Kedarnath. Bathing activity is not significant. With a small population, domestic effluents discharged to the river are not much in quantity.

4. **Srinagar** : Situated at an elevation of 570 metres and 31.3 km downstream of Rudraprayag, Srinagar is an important hill town of Garhwal Himalayan region and has educational institutions, health centre and business centre, and a population of about 8,000 (1977). There is a sizable floating population of those bound for Badrinath and Kedarnath. Pollution due to domestic effluents and soil heaps dumped on the river bank are significant.

5. **Devprayag** : Situated at an elevation of 500 metres and 28.8 km downstream of Srinagar, it is here that the Bhagirathi originating from Gangotri (Gomukh) meets the Alaknanda. After the confluence the river is known as the Ganga. Bathing activity is not very intense and the population is also small.

6. **Rishikesh** : Situated at an elevation of 348 metres and 63 km downstream of Devprayag, the Ganga, after completing the mountainous course enters the plains at this point. It is an important religious and tourist centre with intense bathing activity.

7. **Satyanarayana** : Satyanarayana is an important sampling station with respect to the number of inputs and withdrawals. The Ganga water is diverted into a power channel at Chilla headworks, just 5 km above this station. The Song river, rich in mineral content joins the Ganga at this station. The combined effluents of IDPL and Rishikesh nala also finds its way into the Ganga at this point.

8. **Haridwar** : Haridwar, an important pilgrimage centre is situated 28.3 km downstream of Rishikesh. At the Bhimgauda, waters of the Ganga are diverted to the Upper Ganga Canal, which passes through Hari Ki Pauri. Thousands of people from all over India come to Haridwar to take a holy dip in the river Ganga at Hari Ki Pauri. Though bathing activities continue for most part of the

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* Chapters 20, 21, 22 and 23.

TABLE 5.1

Details of Sampling Stations

WR = Water Regulation
AG = Agricultural Runoff
CB = Community Bathing
CR = Cremation & Post Cremation Activity
DM = Point/Nonpoint Domestic Effluents
ID = Point/Nonpoint Industrial Effluents

	Sampling station	Abvns. in map. 5.1	Distance in km	Elevation in m above M.S.L.	Latitude North	Longitude East	Activities of concern at station
0	Badrinath	Bn	0.0	3086.00	30° 44′ 29″	79° 29′ 41″	CB, DM
1	Nandprayag	Np	71.9	880.00	30° 19′ 53″	79° 19′ 08″	DM, AG
2	Rudraprayag	Rp	118.9	725.00	20° 17′ 09″	78° 59′ 04″	DM, AG
3	Srinagar	Sr	150.2	570.00	30° 13′ 16″	78° 47′ 26″	CB, CR, DM, and AG
4	Devprayag	Dp	179.0	500.00	30° 08′ 54″	78° 36′ 59″	CB, DM, AG
5	Rishikesh	Rs	242.0	348.00	30° 07′ 21″	78° 19′ 10″	CB, CR, DM
6	Chilla HW		250.0	–	–	–	WR
7	Satyanarayana	Sa	259.0	–	29° 57′ 38″	78° 14′ 32″	DM, ID, AG
8	Hari Ki Pauri	Ha	266.7	288.00	29° 57′ 24″	78° 10′ 2 3″	CB, CR
9	Kankhal	Ka	270.3	277.00	29° 55′ 26″	78° 09′ 04″	CB, CR, DM
10	Balawali	Ba	292.5	230.00	29° 37′ 55″	78° 06′ 24″	CR, AG
11	Bijnor	Bi	337.1	–	29° 22′ 55″	78° 04′ 35″	CR, AG, WR
12	Garhmukteshwar	Ga	434.6	195.00	28° 45′ 40″	78° 08 41″	CB, CR, DM, AG
13	Anupshahr	As	491.1	180.00	28° 21′ 27″	78° 16′ 58″	CB, CR, DM, AG
14	Rajghat Narora	Na	509.1	176.00	28° 14′ 32″	78° 21′ 51″	CB, CR, DM, AG
15	Mirzapur	Mz	1191.1	–	25° 09′ 30″	82° 34′ 35″	CB, CR, DM, AG
16	Varanasi	Va	1279.1	–	25° 17′ 00″	83° 00′ 13″	CB, CR, DM, AG, ID
17	Ghazipur	Gp	1338.5	–	25° 34′ 00″	83° 38 10″	CB, CR, DM, AG
18	Buxar	Bu	1384.7	62.30	25° 33′ 30″	84° 57′ 30″	CB, CR, DM, AG
19	Patna	Pa	1532.1	52.13	25° 37′ 00″	85° 09′ 45″	CB, DM, AG
20	Fatuha		1565.1	46.63	25° 30′ 30″	85° 19′ 00″	CB, DM, AG
21	Barh	Ba	1606.7	–	25° 29′ 00″	85° 43′ 00″	CB, CR
22	Mokameh	Mk	1644.1	–	25° 24′ 00″	85° 55′ 00″	ID
23	Munger	Mu	1701.6	30.50	25° 24′ 00″	86° 29′ 00″	CB, CR, DM
24	Sultanganj	Su	1738.8	28.50	25° 15′ 00″	86° 45′ 00″	CB
25	Bhagalpur	Bh	1769.0	25.90	25° 15′ 00″	87° 02′ 00″	DM, ID
26	Maharajpur	Ma	1866.6	22.75	25° 13′ 00″	87° 46′ 00″	AG
27	Rajmahal	Ra	1890.1	21.00	25° 03′ 00″	87° 30′ 00″	Mining
28	Farakka	Fr	1923.2	22.42	24° 51′ 00″	87° 52′ 00″	Fishing

year, the peak is in summer and during the organized bathing festivals such as the Kumbh.

9. Kankhal : Kankhal is the sampling station situated 2 km downstream of Haridwar on the banks of diverted waters from the Upper Ganga Canal. Cremation and post cremation activities are significant on the banks here alongwith the regular bathing activity. Domestic discharges from Kankhal area also meet the Ganga at this point.

10. Balawali : It is 22.5 km downstream of Haridwar and is a cremation place with very little bathing activity.

11. Bijnor : It is situated 44.6 km downstream of Balawali. Cremation by burning is very common here.

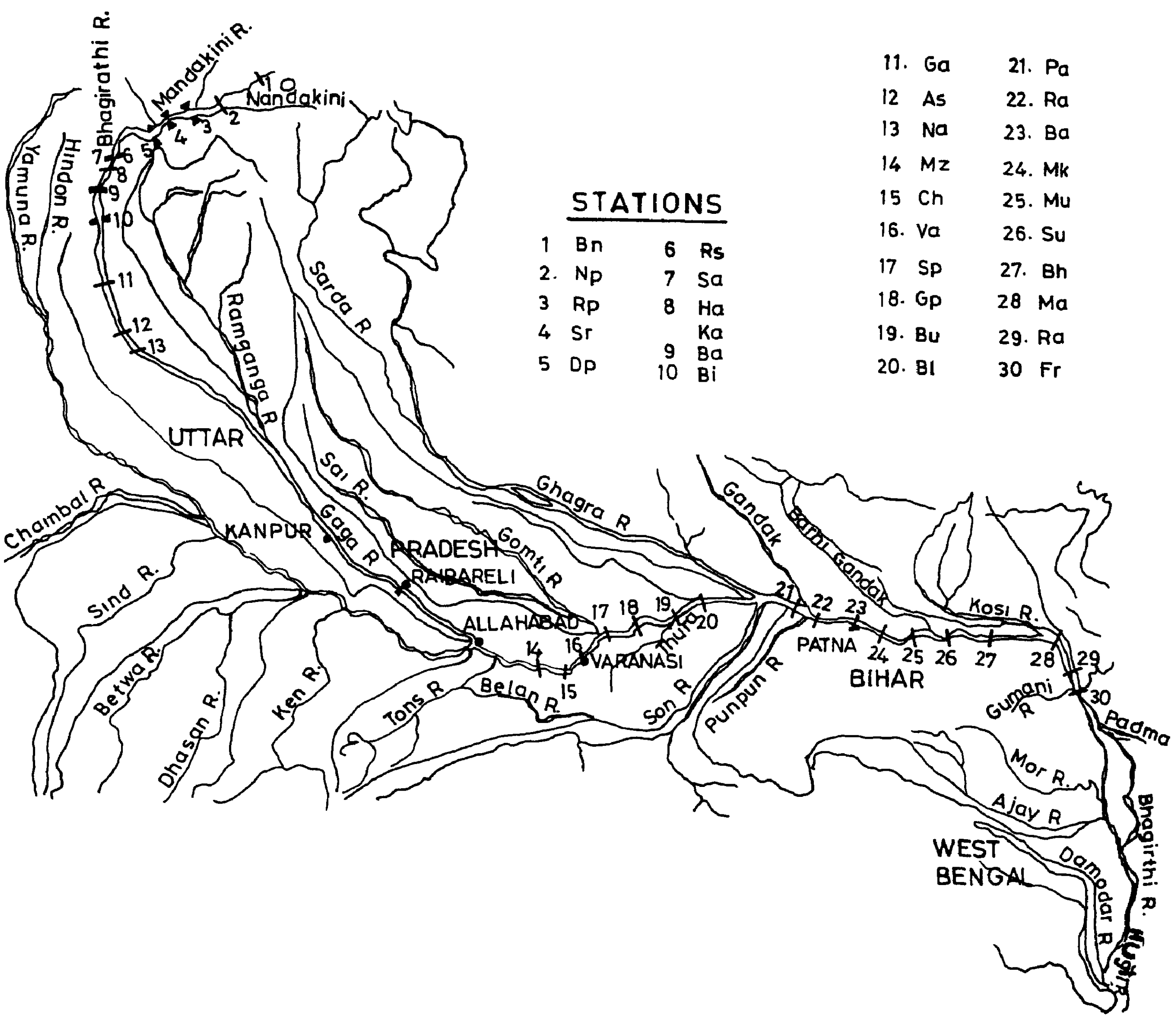

Figure 5.1 : The Ganga Stretch : Badrinath to Farakka
Scale : 1 cm = 61 km

12. Garhmukteshwar : It is 97.5 km downstream of Bijnor and is a spot of religious importance. Bathing activity althrough the year is intense at this station.

13. Anupshahr : Anupshahr is 56.5 km downstream of Garhmukteshwar and is a small town. Bank erosion is very prominent at this station.

14. Narora : Narora is 18.3 km downstream of Anupshahr. The river bed here is used for cremation.

15. Mirzapur : Mirzapur is a district headquarter town situated on the banks of the river. Besides the agricultural return water, bathing and cremation activities on ghats, and industrial and domestic discharges at four major ghats at Mirzapur are significant.

16. Varanasi : Varanasi is a very important religious city situated on the banks of the Ganga river. Bathing and cremation activities are intense on the ghats throughout the year. The significant flow of pilgrims to the city as floating population increases the extent of

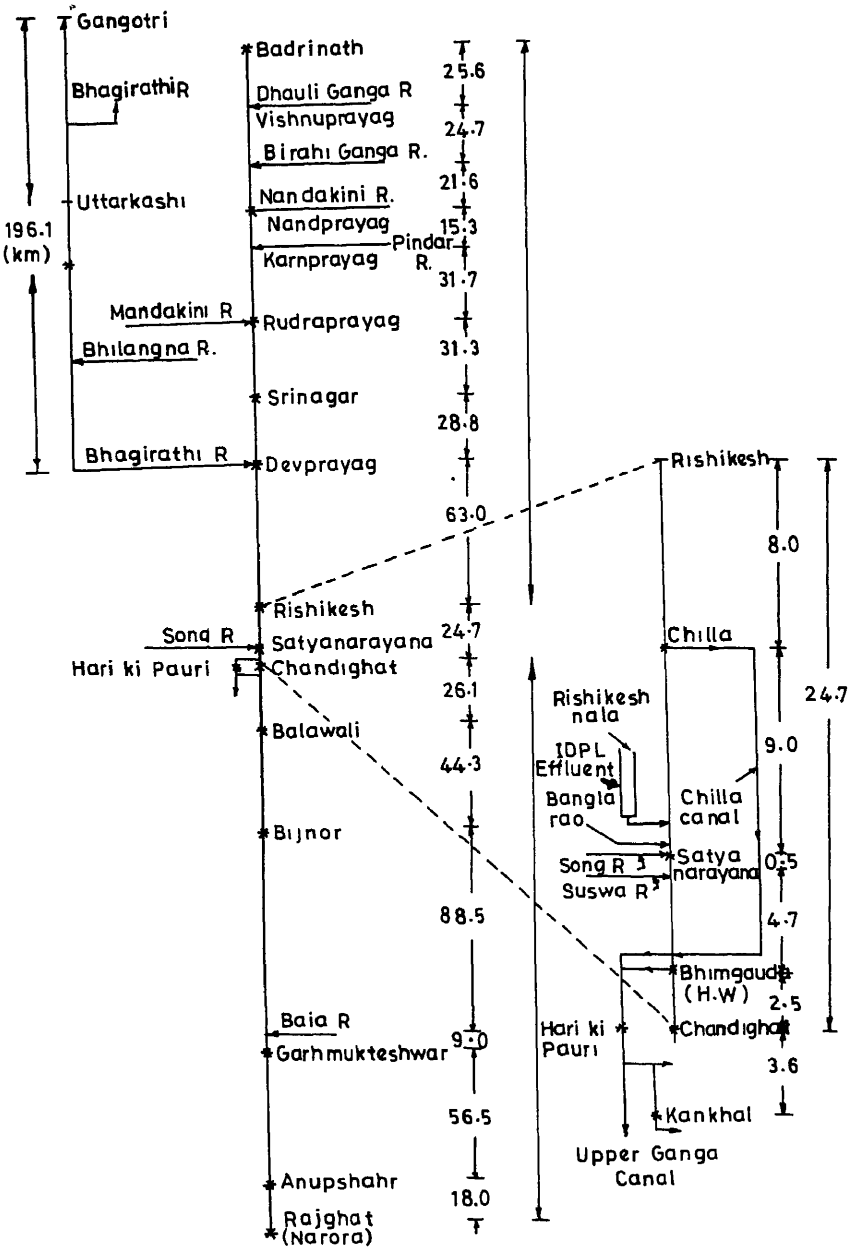

Figure 5.2 : Schematic Diagram of the Ganga River System

domestic and industrial drains adding organics to the aquatic system at a number of places besides numerous nonpoint sources.

17. Ghazipur : Ghazipur is situated downstream of the confluence of Gomti river. Domestic and industrial discharges emanating from the city finds their way into the river. Bathing and cremation are the major activities at the ghats

18. Buxar : Buxar is a subdivisional town where the main activity is agriculture. The agricultural return water flows into the riverine system at many places. Bathing and cremation activities are also significant. No industrial effluents are discharged into the river at this station.

19. Patna : Patna is situated on the banks of Ganga. Cultivation on the left bank is significant with

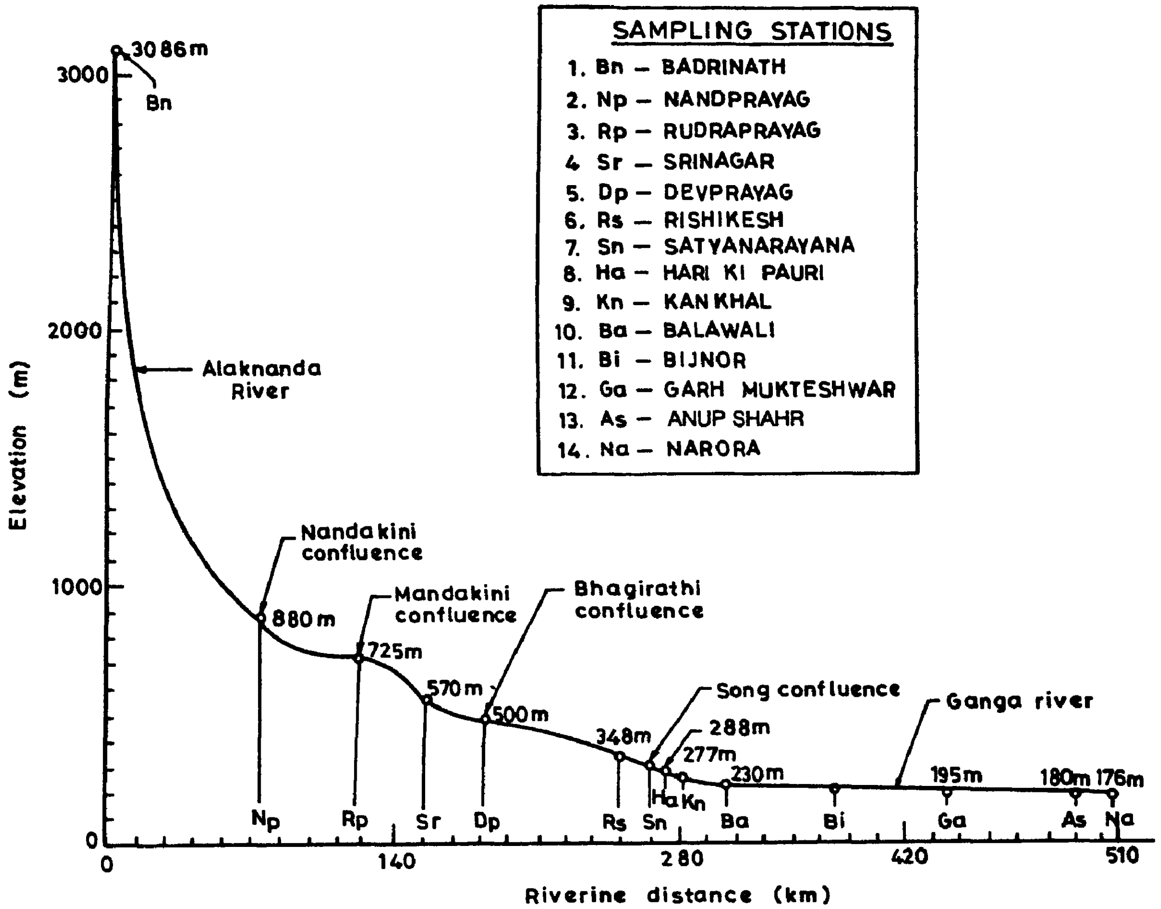

Figure 5.3 : L-Section of the Ganga River (Badrinath to Narora)

input of agricultural return water. Domestic discharges emanating from the city also find their way into the river at number of places. At the ghats bathing and cremation are the major activities. Few small scale industries are situated upstream to Banarjee ghat, but the contribution of discharges is very low.

20. **Fatuha :** The combined waters of the Punpun, the Morhas and the Dordha join the Ganga at this place. Agriculture is the main activity on the left bank. Small amounts of domestic discharges with unorganised bathing and cremation are common on ghats.

21. **Barh :** Agriculture is the major activity, with occasional bathing and cremation at ghats.

22. **Mokameh :** Mokameh is about 30 km downstream to Barh with industrial and agricultural activities. MacDowel, Bata Leather, Oil refinery and Fertilisers are the main industrial discharges in the system.

23. **Munger :** Situated at an elevation of 30.5 metres, the main sewage discharge points at Munger are Kasimbazar, Chuabagh, Citymoat and Chandiasthan.

24. **Sultanganj :** It is situated about 37.2 km downstream of Munger at an elevation of 28.5 metres. Sultanganj is the centre of great pilgrimage which is visited by several lakhs pilgrims during Sawan Mela for only bath in the river.

25. **Bhagalpur :** The divisional headquarters, Bhagalpur is situated on the southern bank, about 30 kms downstream of Sultanganj at an elevation of 25.9 metres. The surface land is plain and drainage is from the west to east. Important sewage discharge points are University outfall, Maniksarkar outfall, Koyalghat outfall, Mansoorganj outfall and Nayabazar outfall. A small tributary Champanala (Jamunianala) also joins the river near Adampurghat. This tributary is heavily polluted with chemicals from the dyeing and silk processing units of Nathnagar and Champanagar.

26. Maharajpur : Situated at an elevation of 22.75 metres and 97.6 km downstream of Bhagalpur there is no important input/withdrawal to the river system at this station except agricultural run-off from the surrounding catchment areas.

27. Rajmahal : Situated at an elevation of 21 metres and about 23.5 km downstream of Maharajpur it is an important centre for mining activity.

28. Farakka : Situated at an elevation of 22.4 metres and 33.1 km downstream of Rajmahal Farakka is the most important fishing centre of this range.

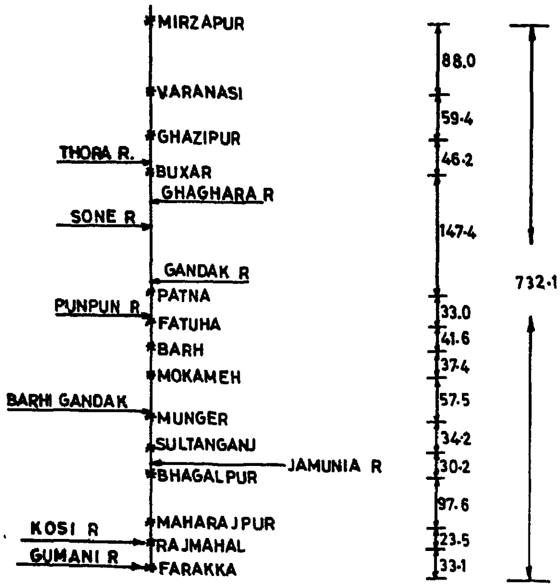

Figure 5.4 : Conceptual Linearised Diagram of the Ganga River (Mirzapur to Farakka)

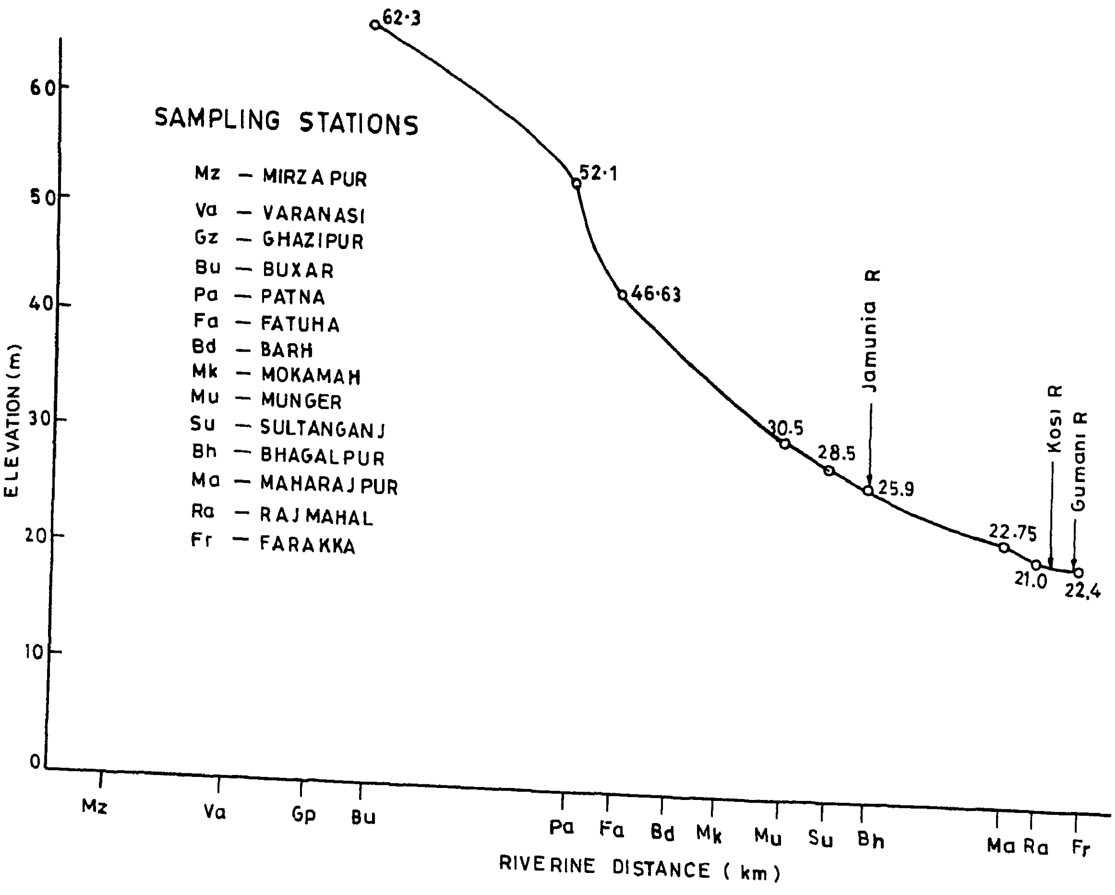

Figure 5.5 : L-Section of the Ganga (Mirzapur to Farakka)

6

Trend of Physico-chemical Characteristics of the Ganga Water

R. P. MATHUR

Water Temperature

The surface water temperatures exhibited an expected seasonal pattern. The maximum value of 32.3° C was observed at Patna in the summer of 1985 and the minimum of 9.6° C at Nandprayag in the winter of 1985 excluding Badrinath where temperatures varied

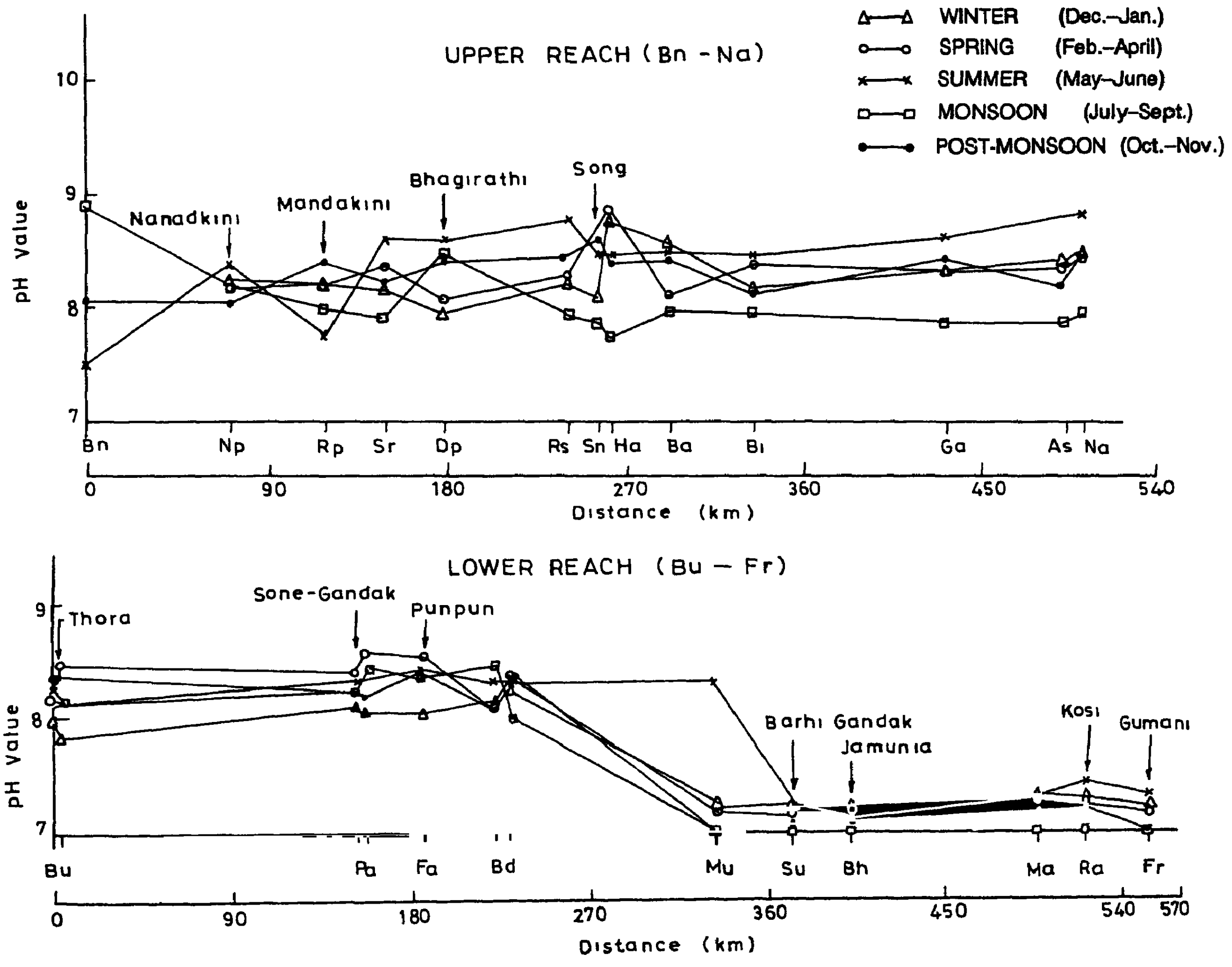

Figure 6.1 : Variation in *p*H

between 2.4 and 8° C in summer to postmonsoon seasons. The values were almost in the increasing order along the course of the river. From Bijnor to Narora the values were nearly same. The only point which deviated significantly, was Satyanarayana where the lowest coefficient of variation and lowest range of temperature (15 – 26° C) were observed. Both maximum and minimum values recorded were high in comparison to upstream and downstream stations because of the contributions of the Song river. In the lower stretch the temperatures of water and surroundings were almost constant at all the sites. However, the impact of seasons on water temperature was maximum (32.3° C) at Patna during monsoon and minimum at Munger in winter (18.6° C).

*p*H

[*p*H is a general physico-chemical parameter and indicates the fate of chemical constituents. The *p*H was generally around 8.0 throughout the stretch indicating that the Ganga river is slightly alkaline.] Variations in the general trend were observed between Mirzapur and

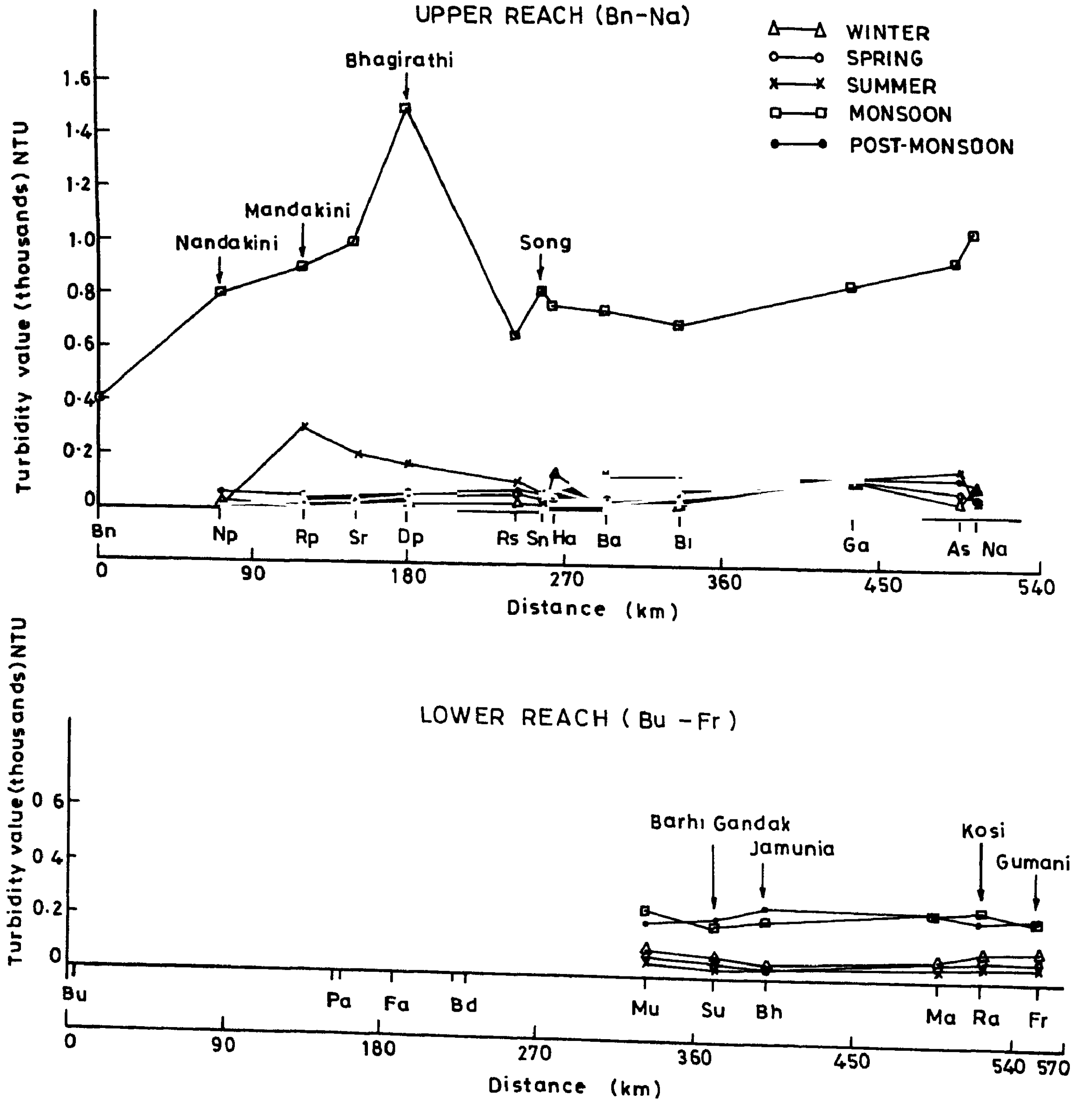

Figure 6.2 : Variation in Turbidity

Varanasi (annual mean 7.56 – 8.0) and downstream of Barh. The sharp decline between Barh and Munger cannot be explained on the basis of any distinct phenomenon, although experimental error cannot be altogether excluded.

Variations in profile are shown in Figure 6.1

Oxidation Reduction Potential

Oxidation Reduction Potential (ORP) is closely related to *p*H and reflects the state and migration conditions of minerals to waters and in general the geochemical changes that occur in the river stretch. The values of ORP were positive indicating the prevailing oxidative state of the river. The values ranged between 103 and 365 mV. The values were generally higher in mountainous region than in plains. No data from the lower reach is available to indicate the trend.

Turbidity

In the upper stretch, turbidity of the river varied appreciably in different seasons. High turbidity was observed at all the sampling stations during the monsoon (range 350–1550 NTU). The confluence of Bhagirathi with Alaknanda adds significant amount of suspended load as there is intense activity and erosion in the Bhagirathi catchment. The variations in lean period was between 5 – 150 and post-monsoon 35 – 157 NTU. The spatial variations were also significant.

In the mountainous stretch the values marginally increased due to the addition by the tributaries, at different sampling stations. The values declined at Rishikesh, in plains, due to marginal settling (reduced turbulence) of suspended solids, and again decreased at Satyanarayana as the Song carried relatively low turbidity water even during the monsoon.

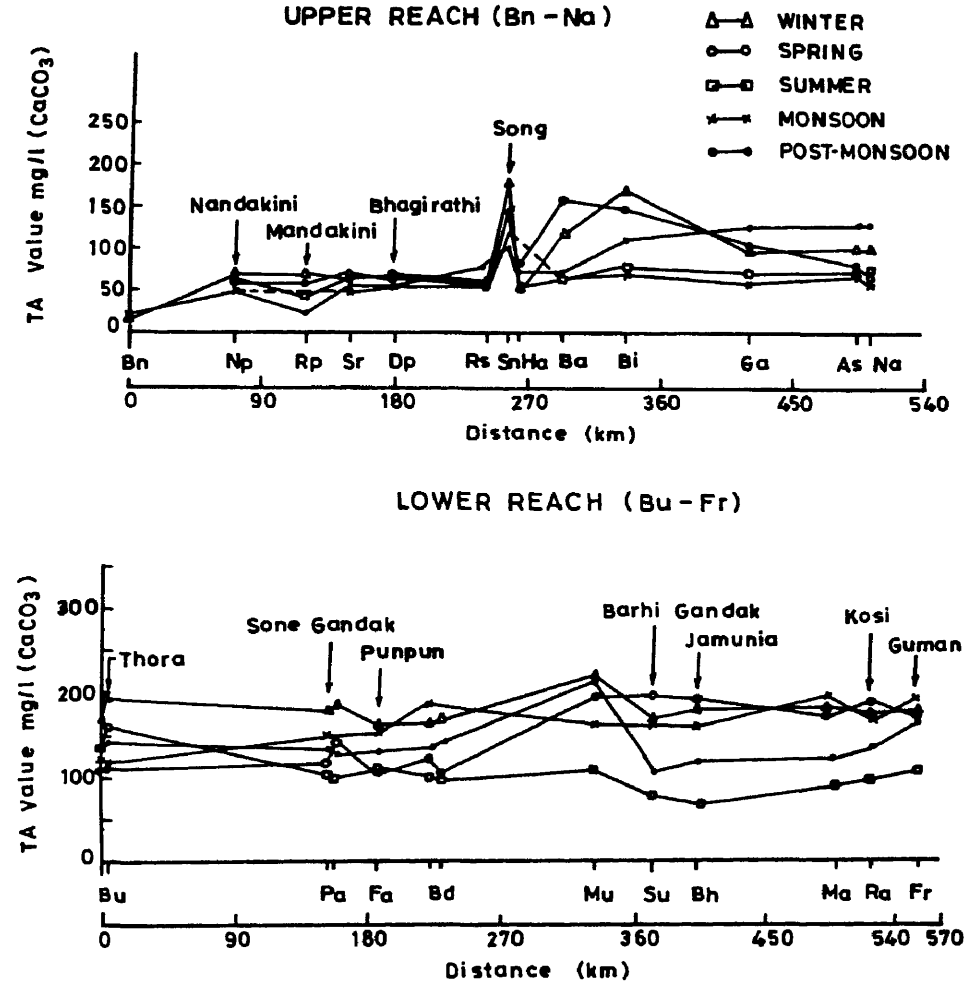

Figure 6.3 : Variation in Total Alkalinity

All the tributaries add significant load in monsoon season.

Fluctuation in the plains was, however, marginal depending on seasons and human activity. The data from Buxar to Barh in the lower stretch is not sufficient to make even tentative conclusions. However, a minimum of 49.7 NTU at Bhagalpur in spring and a maximum of 268.7 NTU at Munger in rainy season were recorded. The range was 197–268 NTU in the monsoon, 51–122 NTU in winter and 69–85 NTU in summer. The profiles of turbidity are presented in Figure 6.2.

Conductivity

Conductivity reflects the mineral/ionic status of the aquatic system. In the upper mountainous stretch the range of mean conductance (Nandprayag to Rishikesh) was 22.47-222.0 µmhos/cm. Further down at Satyanarayana, there was a sudden spurt to 571.6 µmhos/cm (spring) due to the effect of the highly mineralised tributary Song making the temporal changes in the conductivity values quite distinct. Values showed a major increase during the lean flow season with low values in the high flow season, indicating a typical dilution pattern. The mean value at Badrinath, (sampled 3 times in summer to postmonsoon season) was registered as 60 µmhos/cm. The highest coefficient of variation was observed at Nandprayag and the lowest at Satyanarayana.

In the lower stretch the values ranged from 460 – 796 µmhos/cm between Mirzapur and Ghazipur and 75 – 354 µmhos/cm from Munger to Farakka. The reason for these sharp variations can only be attributed to dilution through Thora river. The comparison of the values between the upper and lower stretch reveal a comparatively poor nutritional status of the upper Ganga.

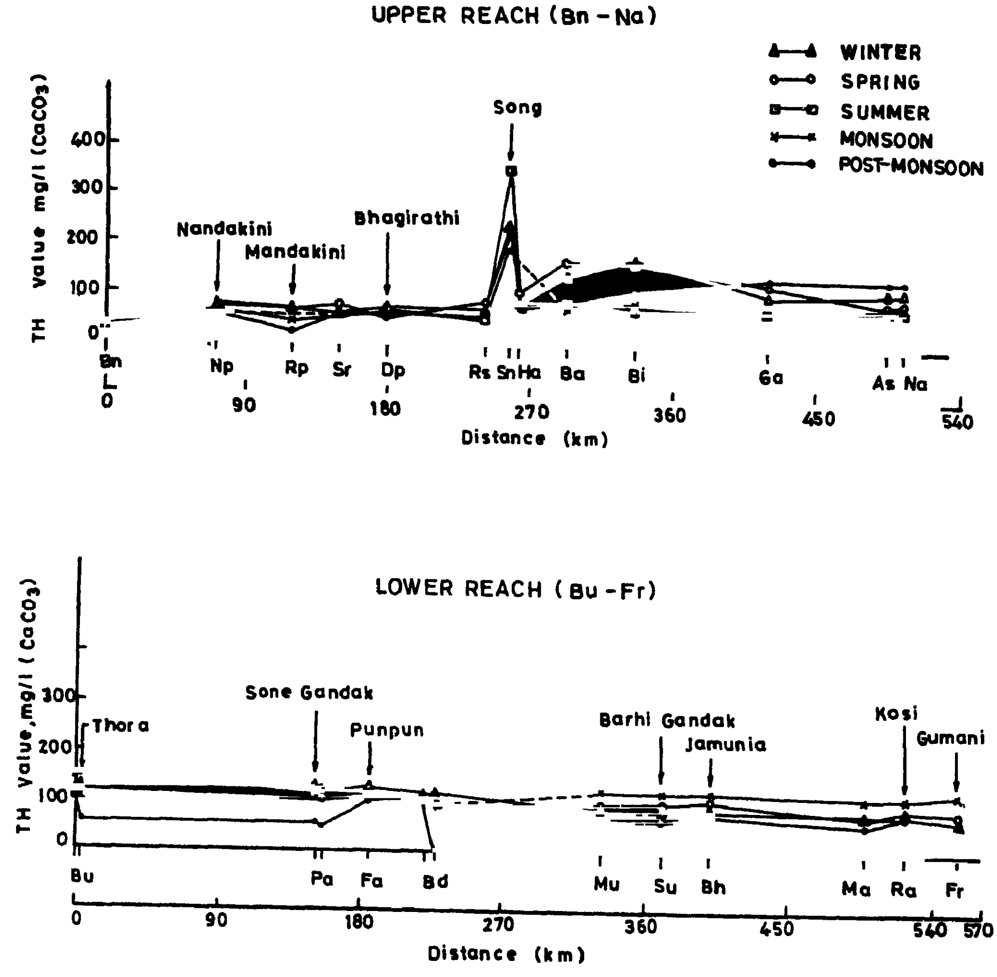

Figure 6.4 : Variation in Hardness

Total Alkalinity

The predominant form of alkalinity in the Ganga river was due to bicarbonates as the *p*H values were below 8.3 except at Badrinath. A distinct pattern was evident in the upper stretch where the values remained below 100 mg/l even at confluences. The only significant change was at Satyanarayana where the maximum value recorded was 179 mg/l. This could be attributed to the river Song which drains limestone deposits in the Dehradun – Maldevta area. The values downstream showed a marginal increase to 60–160 mg/l. This may be due to ground water interactions. The seasonal variations were not significant but were manifest in lean, monsoon and post monsoon seasons.

In the stretch between Mirzapur and Ghazipur the values varied between 150 – 225 mg/l while between Buxar to Farakka the range was between 69.2–221 mg/l. Alkalinity in the entire range fluctuated within a narrow band due to high buffering capacity of the river (Figure 6.3).

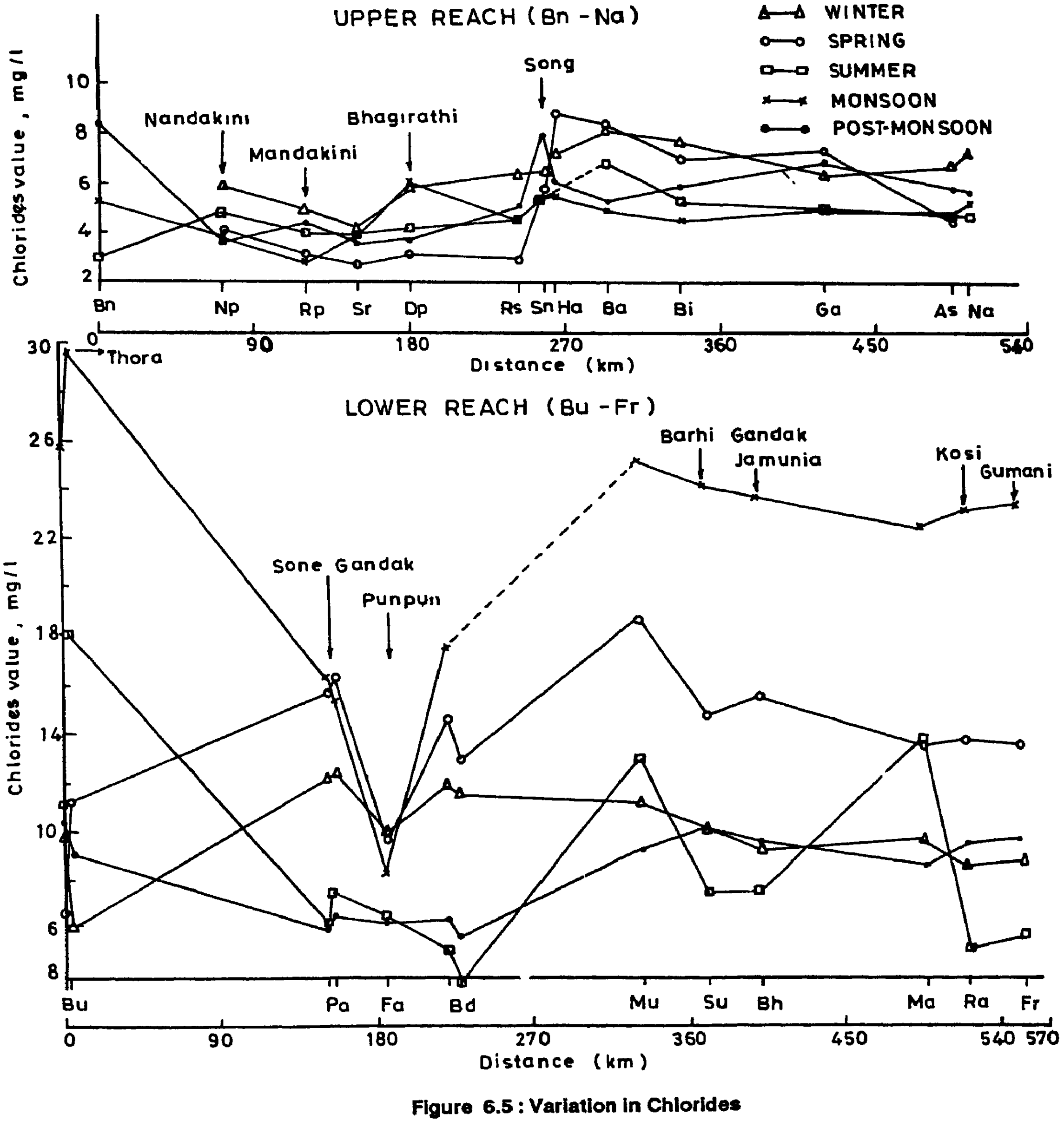

Figure 6.5 : Variation in Chlorides

The range in different seasons was 14.8 - 197.0 mg/l in summer, 20.5 - 198 mg/l in the rainy season and 58.6–221 mg/l in winter.

Total Hardness

Total hardness (TH) predominantly due to calcium and magnesium ions as chloride, bicarbonate and sulfate is generally low in the Ganga system and renders the water soft. There are, however, fluctuations as expected due to additions from different drainage basins like the Song.

The values do not show any major temporal and spatial variation except minor alteration at confluence points. The data of lower stretch does not show expected correlation as at many places hardness values reported were lower than alkalinity. This evades a possible explanation of pseudohardness.

Variation in general were between 16 to 194 mg/l in summer, 23 - 353 mg/l in rainy season and 58 - 242 mg/l in winter. The profiles are shown in Figure 6.4.

Chlorides

The strata of the entire Ganga basin is such that it adds very little of chlorides during the flow. The value of Chloride ion is low throughout with a minimum of 2.8 mg/l and a maximum of 29.8 mg/l. However, the values reported between Mirzapur and Ghazipur the variation was between 34.3 to 70.8 mg/l. The temporal as well as spatial variations were also of a very low order (Figure 6.5).

The concentration of chlorides reflects basically the presence of dolomites in the mountainous reach where the input from domestic sources is insignificant. The only worthwhile load is through bathing which is predominant throughout the stretch.

The discharge of domestic effluents at Srinagar, Devprayag, Garhmukteshwar, Anupshahr and almost all places downstream and increased bathing and cremation load increases the salinity gradually.

The general load variation was between 3.0 to 29.8 mg/l in summer, 2.8 to 18.0 mg/l monsoon and 4.2 to 12.8 mg/l in winter.

Solids — Total Suspended and Total Dissolved

The amount of total solids and its variation along the course of the river indicates the extent of erosion and weathering in the riverine catchment. In general, where the physical erosion is prominent, the suspended solids constitute the main portion of the total solids. In the mountainous reaches, the total solids content showed a decreasing trend between Nandprayag and Devprayag (Figure 6.6). At Devprayag, Bhagirathi added large amounts of total suspended load as anticipated due to intense construction activities in the catchment. At Satyanarayana the total solids concentration reached the maximum value of 905 mg/l attributed to the additions by the Song river.

Downstream of Satyanarayana the values decreased except in monsoon season where surface runoff contributes to both total and dissolved solids.

The seasonal values of total dissolved (TDS) and suspended solids (TSS) reported for the stretch between Munger to Farakka are given in Table 6.1.

TABLE 6.1

Seasonal Values of TDS and TSS between Munger and Farakka

Parameter	Min.Value	Season	Location	Max. Value	Season	Location
TDS	165.0 mg/l	Summer	Rajmahal	286.0 mg/l	Summer	Bhagalpur
TDS	133.0 mg/l	Monsoon	Rajmahal	235.0 mg/l	Monsoon	Bhagalpur
TDS	195.0 mg/l	Winter	Bhagalpur	220.0 mg/l	Winter	Munger
TSS	60.0 mg/l	Summer	Maharajpur	119.0 mg/l	Summer	Bhagalpur
TSS	105.0 mg/l	Monsoon	Sultanganj	339.5 mg/l	Monsoon	Sultanganj
TSS	78.0 mg/l	Winter	Bhagalpur	102.5 mg/l	Winter	Maharajpur

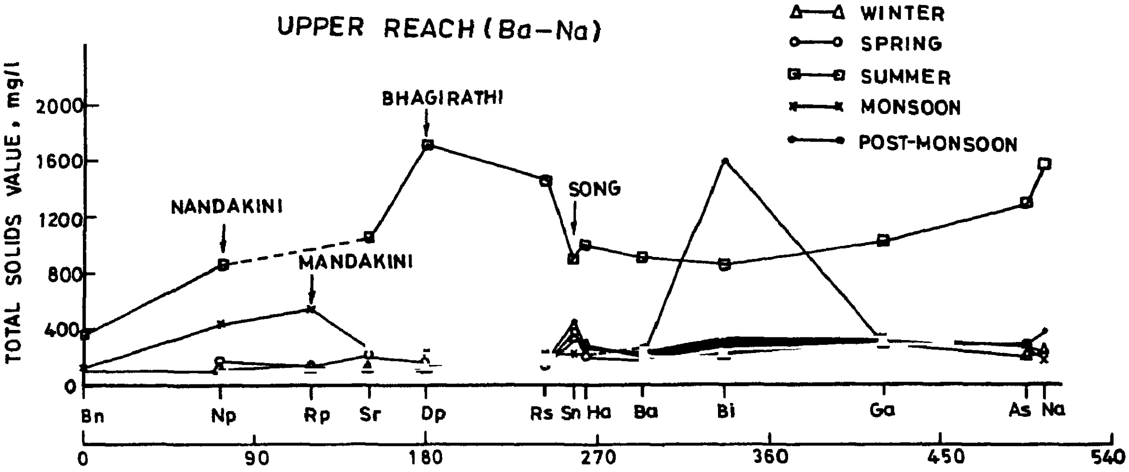

Figure 6.6 : Variation in Total Solids

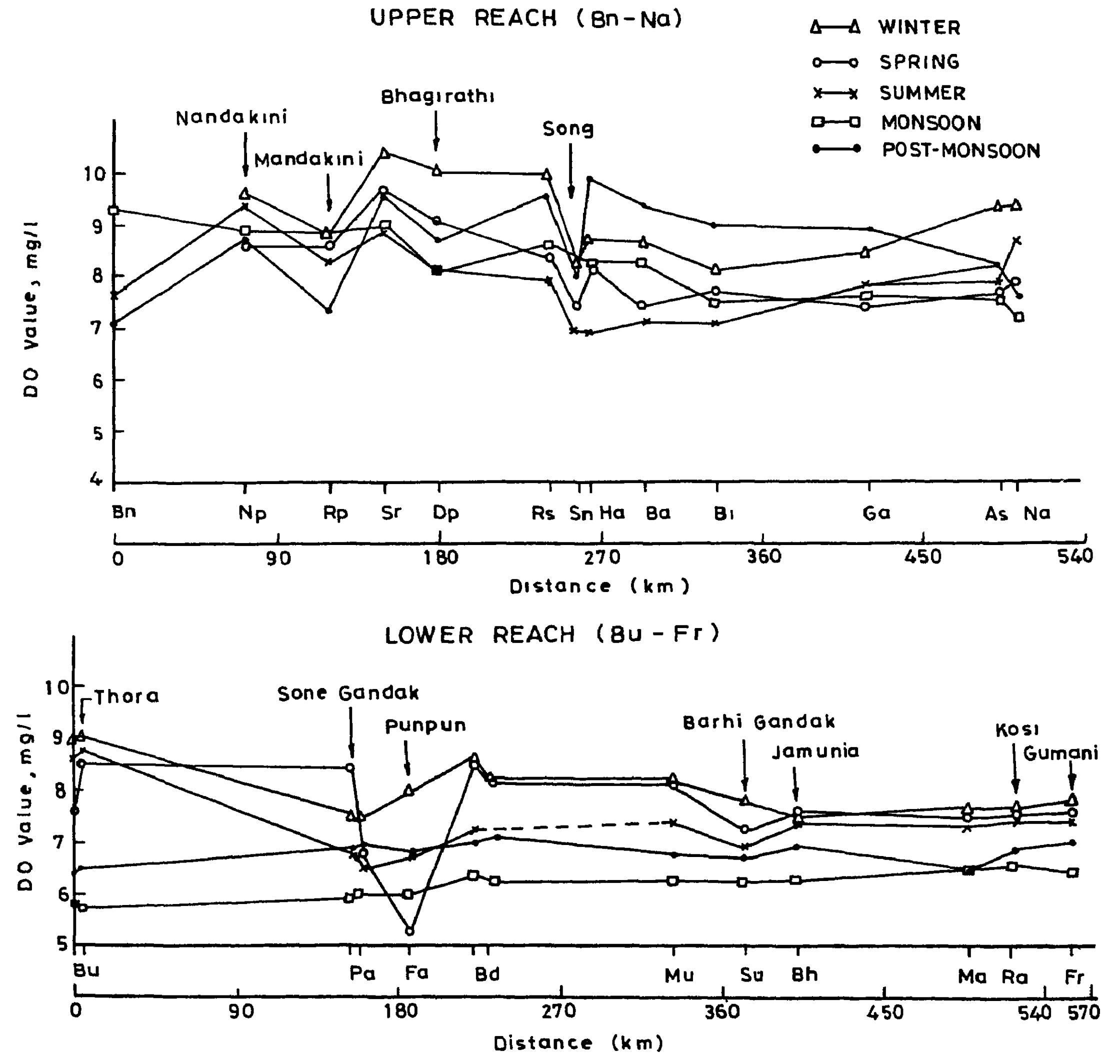

Figure 6.7 : Variation in Dissolved Oxygen

Suspended solids showed a direct and significant relationship with turbidity and dissolved solids with conductivity.

Calcium and Magnesium

Between Nandprayag and Rudraprayag the calcium values decreased (22.0 - 18 mg/l) and the magnesium values increased (4.9 - 5.1 mg/l) indicating that the rocks of this stretch were basically magnesites. In contrast, magnesium showed a decreasing and calcium an increasing trend between Rudraprayag and Srinagar presumably due to the presence of dolomite rocks. The trends were similar from Srinagar to Rishikesh. At Satyanarayana both the calcium (60 mg/l) and magnesium (18 mg/l) increase due to addition of the Song water. Between Balawali and Bijnor calcium content increased (30-38 mg/l) whereas magnesium was constant. Downstream of Bijnor, the values decreased (Ca - 30 mg/l, Mg - 7.0 mg/l) and were of the same range upto Rajghat Narora.

No values were available between Mirzapur and Ghazipur. In the stretch between Munger to Farakka the concentration of calcium was maximum (44.3 mg/l) at Sultanganj in the summer and minimum (6.2 mg/l) at Bhagalpur during the monsoon. The ranges in different seasons were 19.2 - 44.3 in summer, 6.2 - 22.6 in the rainy season and 11.4 - 24.6 mg/l in winter. The values were lowest during rains and highest during winter followed by summer at all the sites. The maximum value for magnesium of 16.49 mg/l was reported at Bhagalpur during summer and minimum, (1.68 mg/l) at the same site in the rainy season. The concentration was always less than that of calcium and ranged between 6.48-16.49 mg/l in summer, 1.68-11.78 mg/l in the rainy season and 3.91-14.58 mg/l in winter.

Sulphates

Sulphates are low in the upper reaches from Nandprayag to Rishikesh (ranging between 15.0 - 20.0 mg/l) indicating no prominent contribution from geological activity. The increase at Satyanarayana indicates the input of sulphates in the Song from the catchment area which has pyritic and dolomite deposits in the Doon valley. (The value at Satyanarayana varied between 102-265 mg/l). Thus the waters of the Song and the ground water of the Song basin are rich in sulphate as compared to the Alakananda basin. Downstream of Satyanarayana sulphate showed a decreasing trend similar to other mineral parameters (between 10.0-40.0 mg/l) indicating the seepage of ground water in lean flow months and slight dilution caused by the Baia at Tigri.

No data is available for the stretch between Mirzapur and Ghazipur and Munger to Farakka. However, the

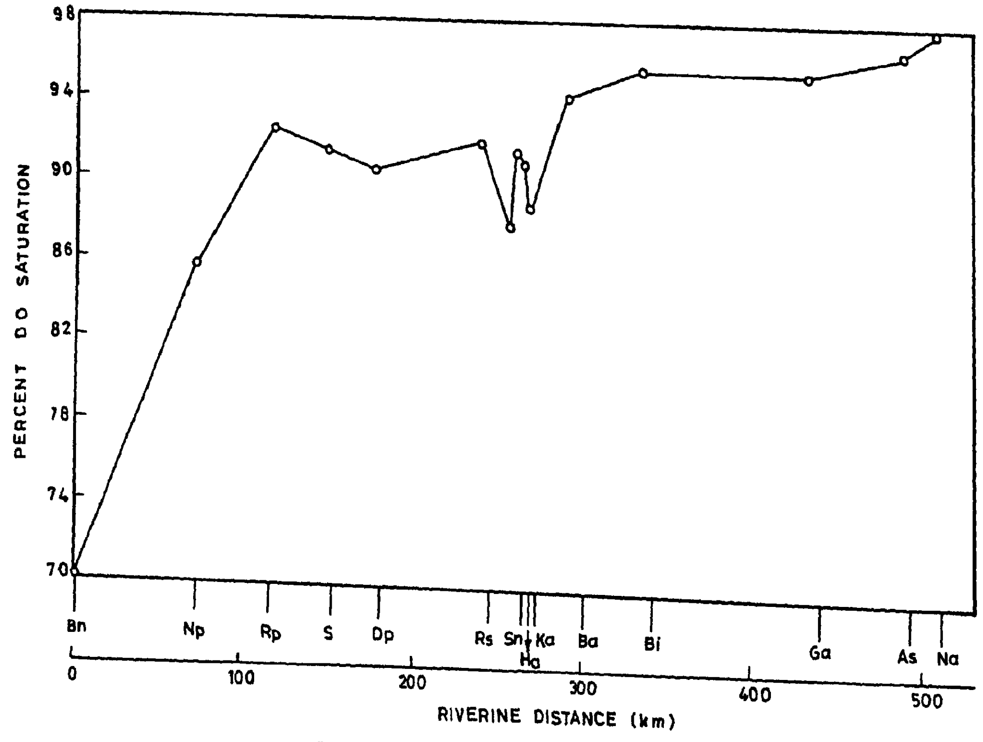

Figure 6.8 : Spatial Variation of per cent D.O. Saturation

values between Buxar-Barh showed variation in the range of 8.03–31.95 indicating low sulfate values. The values during monsoon and postmonsoon are higher than in winter and summer.

Dissolved Oxygen

The Dissolved Oxygen (DO), a parameter to indicate the overall health of the stream was relatively high in the upper reach but in the stretch between Mirzapur and Ghazipur and further down Buxar-Farakka was low. The values varied between 10.4 mg/l at Rudraprayag and Srinagar and 3.8 mg/l at Ghazipur (Figure 6.7).

In the upper reach the lowest saturation value was 70 per cent at Badrinath and around hundred per cent in plains (Figure 6.8). The low value at Badrinath is in agreement of observations made by Schreirev in 1980 on Arctic and Subarctic river basins. The overall trend in the DO concentration was fairly consistent throughout the stretch although a deviation was noted at Satyanarayana. The comparatively low values at this station was perhaps due to the discharges of IDPL industries effluents and the city's wastes but the depletion was marginal. Thus DO showed relatively small regional and seasonal fluctuations.

In the stretch between Mirzapur and Ghazipur, the depletion seems to be significant and the values vary between 3.8 mg/l at Ghazipur to 6.4 at Varanasi. The river tends to respond to the addition and assimilation as it flows down.

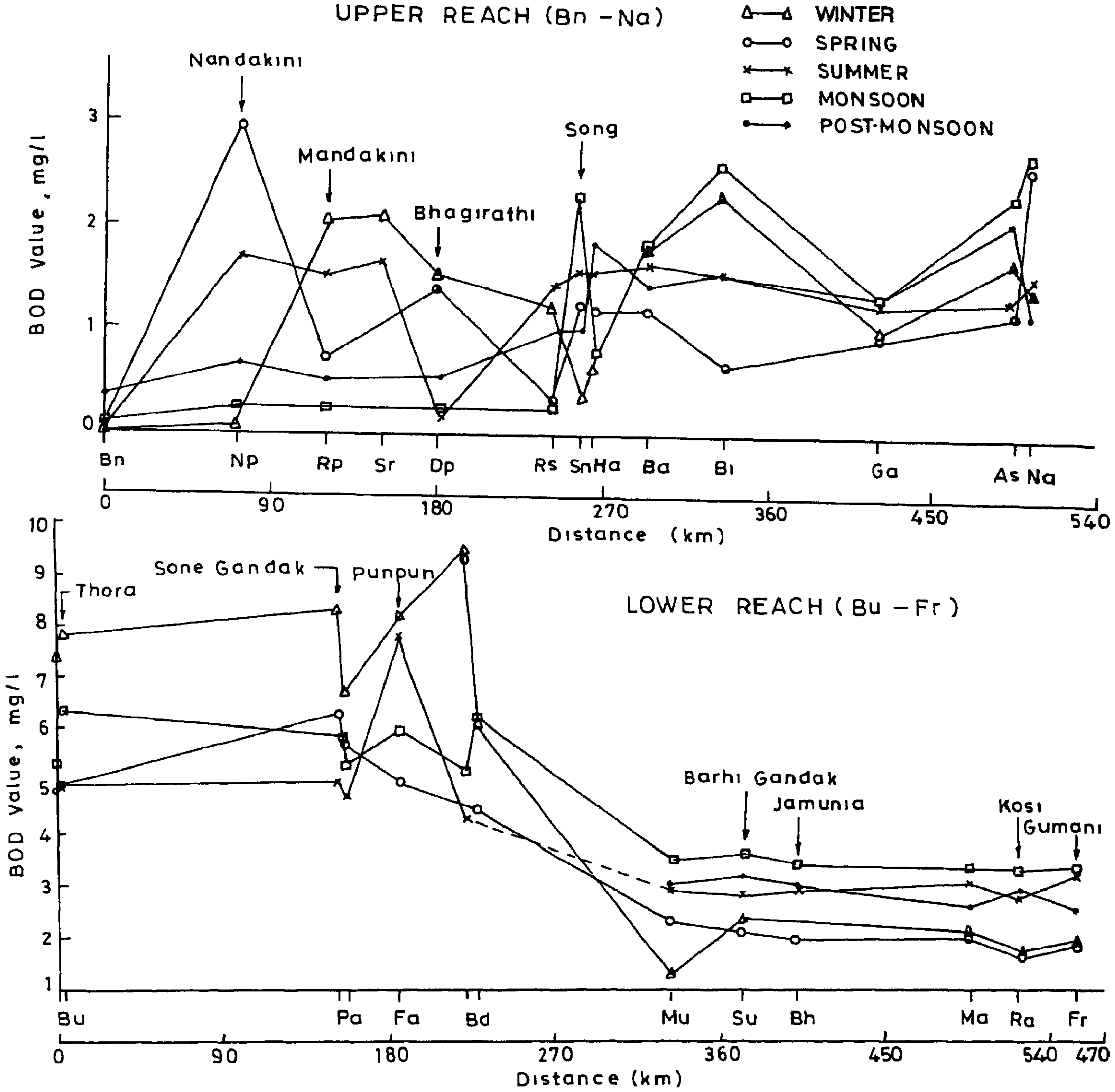

Figure 6.9 : Profiles of BOD Variation

In the lower stretch the maximum value of 9.0 mg/l was recorded at Buxar during summer and minimum of 5.2 mg/l at Fatuha in the spring and ranged from 6.4 – 8.8 mg/l in summer, 5.8 – 6.5 mg/l in the rainy season and 6.7 – 9.0 mg/l in winter. The variation was not very significant in the entire stretch except for a large deviation at Fatuha in the spring. The low value of 5.2 mg/l recorded at this station evades explanation from the data available.

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) of the river Ganga fluctuated between 0.1 mg/l at Badrinath and 8.4 mg/l at Barh. The values reported between Mirzapur and Ghazipur are too high to comprehend (56.0 – 78.9 mg/l) as they seem to be waste waters.

The BOD of the water samples in the upper stretch was usually low and the range was from 0.10 – 2.8 mg/l. The mean BOD values were registered between 0.2 and 1.98 at Badrinath and Bijnor respectively. The point of anomaly was Devprayag where the BOD values decreased slightly. In general the BOD values were high in monsoon and post monsoon season. Low values were recorded during summer. Low BOD values and high oxygen values indicate a vigorous assimilation activity in the upper Ganga.

Value at all stations except Satyanarayana and Bijnor were below the limit set for waters for organised outdoor bathing. At these stations 90 percentile values were registered below the limit (Figure 6.11) Thus compared with other areas exposed to human activities, the area studied seems to be unpolluted and presents pristine standards.

In the lower stretch slightly high BOD values were recorded from Buxar to Barh. Bata industries at Barh and Oil refinery at Barauni contribute largely to the BOD load in the river. The maximum BOD.recorded was around 8.4

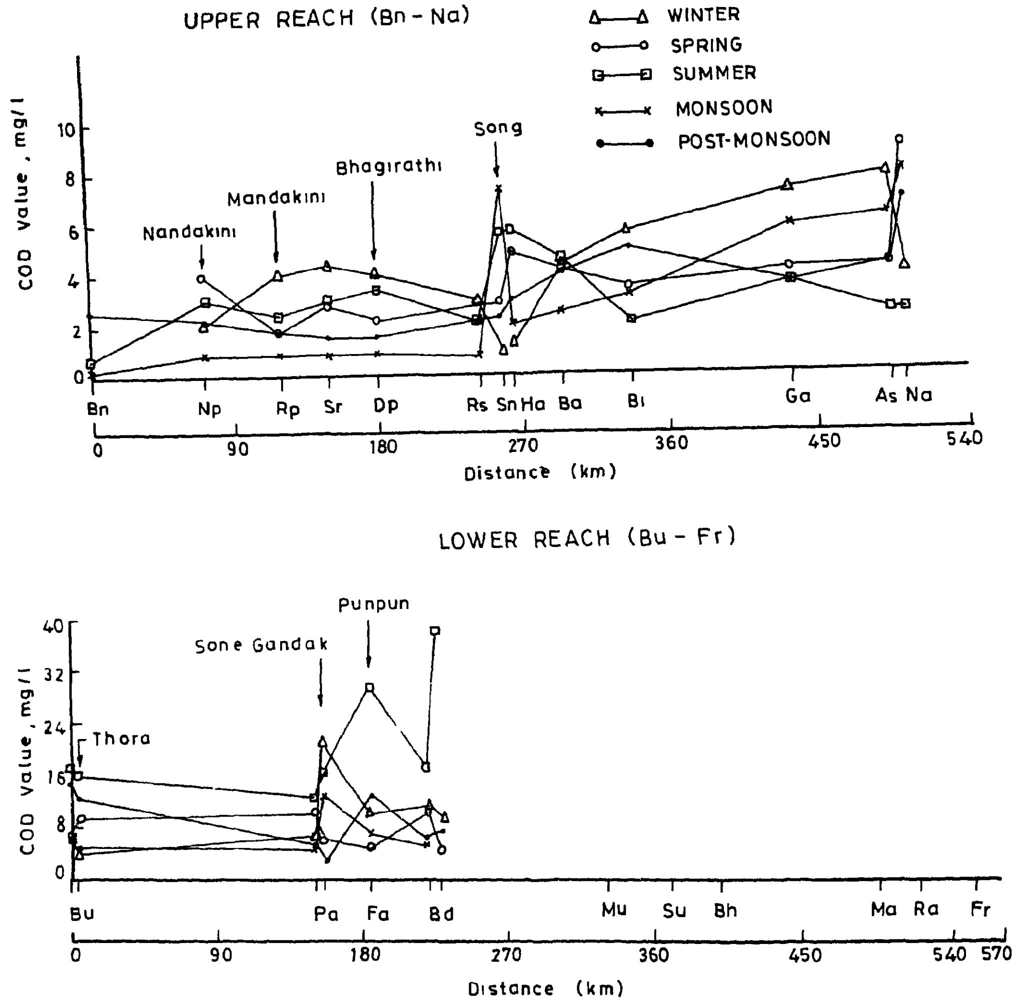

Figure 6.10 : Variation in COD

at Barh in winter and the lowest value was 0.3 mg/l at Munger during winter. It ranged from 1.87 – 6.8 in summer, 2.3 – 5.5 in rainy season and 0.3 – 8.5 in winter. At sites of confluences and ghats the BOD values were high as expected due to increased microbial population and excess of organic matter (Figure 6.9).

Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is an estimate of total oxidisable organic material in waters. The variation of BOD and COD were generally of the same magnitude and at most places a ratio of 1.0 COD to 0.6 BOD was observed. There was disagreement to this ratio at some station in the lower reach indicating the presence of non-biodegradable oxidisable matter.

In the upper stretch from Badrinath to Rishikesh, COD values were in the range 0.30 to 3.4 mg/l the lowest being at Badrinath (Figure 6.10).

In the foothills the values were nearer to 3.1 mg/l, while in the plains from Balawali to Narora, the values were

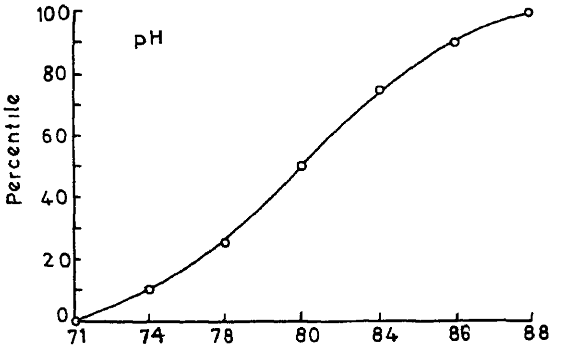

Fig. A. pH Values

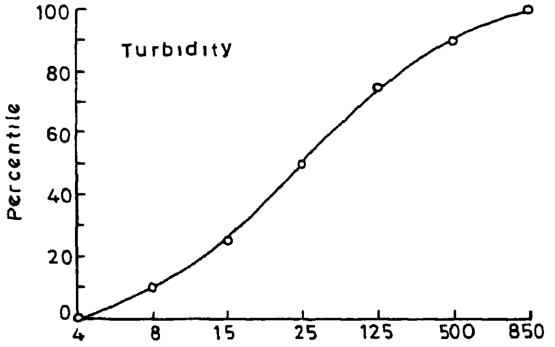

Fig. B. Turbidity values (N.T.U.)

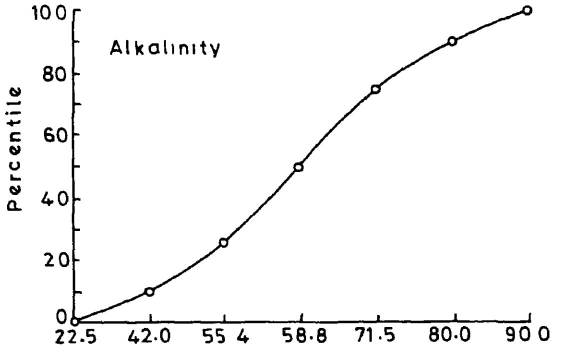

Fig. C. Alkalinity values (mg/l CaCo3)

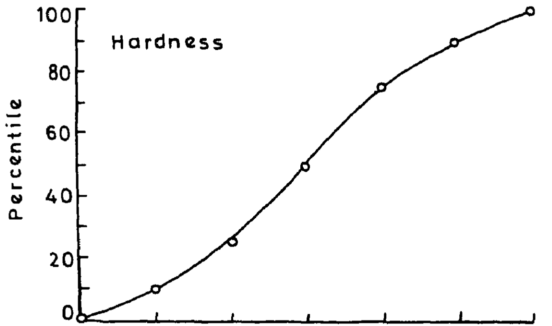

Fig. D. Hardness values (mg/l CaCo3)

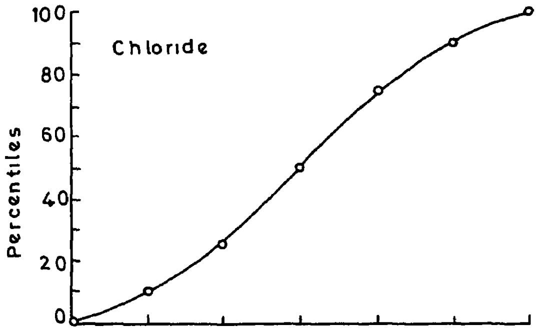

Fig. E. Chloride values (mg/l Cl⁻)

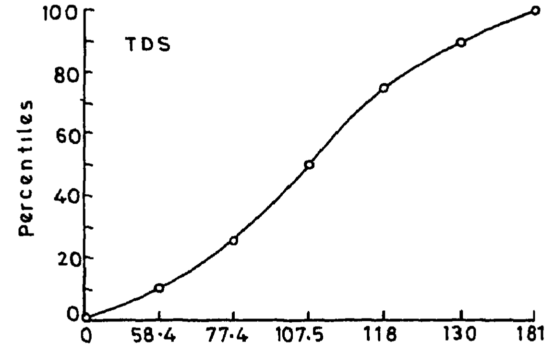

Fig. F. TDS Values (mg/l)

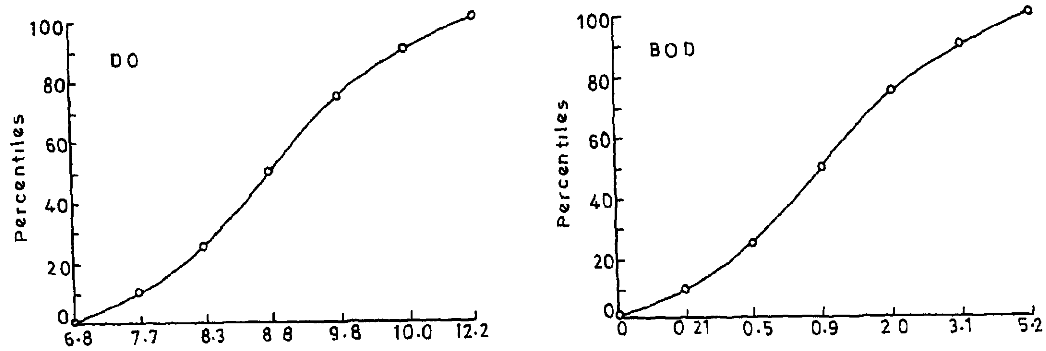

Fig. G. DO Values (mg/l)

Fig. H. BOD Values (mg/l)

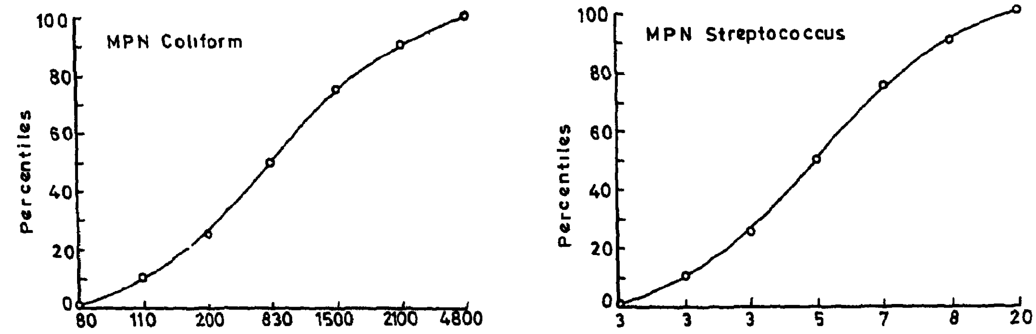

Fig. I. MPN Coliform values (100 ml)

Fig. J MPN Streptococcus values (/100 ml)

Figure 6.11 : G – J : Pristine Ranges

between 2.09 and 8.8 mg/l. At Bijnor the values found were the highest which could be attributed to the presence of organised cremation by burning. At these points where oxygen saturation values decreased due to the impact of domestic effluent, the COD values showed an upward trend.

In the lower stretch between Buxar to Farakka the maximum value reported was 39 mg/l at Barh with fluctuations from 1.4 to 13.1 mg/l in summer, 10.86 – 39 mg/l in the rainy season and 6.0 – 21.2 mg/l in winter. The values reported were higher from Patna to Barh due to higher organic load from domestic and primarily industrial effluents in the above region. The data presented between Mirzapur and Ghazipur does not fall into the general trend. The values reported were between 160.0 – 214 mg/l.

Pristine Quality Variations

For getting a realistic picture of spatial variability along the river in the values of the various water quality parameters, cumulative frequency distributions were developed and measured at selected locations viz., Nandaprayag and Rudraprayag on the Alaknanda river stretch in the Ganga system. These stations have been selected primarily because:

(i) they represent a relatively pure and unpolluted zone of the upper Ganga; the Alakananda river stretch being superior to the Bhagirathi river stretch because of lesser ongoing activities and developmental projects in the catchment.

(ii) these have the advantages of having being continuously monitored for a period of two years at regular intervals.

The distributions in the percentile forms represent the pristine states of the said parameters in the system. When compared to their values at respective downstream stations along the river, the deviations are supposed to exhibit a better picture of the realistic variation in the state of river quality. Following parameters have been considered for computing the frequency distributions: pH, Turbidity, Alkalinity, Hardness, Chlorides, TDS, DO, BOD, Total Coliform, Fecal Streptococci (Figures 6.11 A – J)

7

Mathematical Modelling of Water Quality

HIMANSHU JOSHI AND R. P. MATHUR

"A Model is an abstraction or simplification of a system" (Hall and Day, 1978). The ultimate objective of modelling is to explore the Function and Structure of nature in general, whose complexities, appear to be dumb founding. Identifying and understanding the causal phenomena underlying various isolated processes and components within the system and their integration proves to be a very strong tool in the hands of the scientists and engineers. The model provides unique information about the system behaviour, typified by new or emergent characteristics, many a time different from the ones of the isolated components. It is for the same reasons that water quality modelling has been incorporated to aid the conceptualisation, understanding, measurement and prediction of the behaviour of the Ganga Ecosystem.

A large variety of models of varying nature and category are available today. The approach basic to most of them is the mathematical representation of the causal behaviour of the nature.

Simulation being one of the most common modelling approaches is possibly due to the following reasons : –

- It allows the researchers to solve a large number of mathematical equations simultaneously thereby providing ample scope for a realistic consideration of large number of component interactions.
- It allows the researchers to incorporate the complex nonlinearity in the mathematical formulations, which prevents them from making unrealistic simplifications in the system behaviour.
- It allows the researchers to take full advantage of the present day high speed components, as it is ideally suited for the same.

Model Selection

Ideally, models should be constructed so as to specially suit different conditions of their intended application. However, for the reasons like huge requirements of time, infrastructural resources and expertise, a slightly different approach of selecting a model out of several well-documented, calibrated and verified models used elsewhere and later applying it in the desired case does sound equally attractive and in fact, is widely practised. Meanwhile, this approach demands a prior in-depth evaluation of the local conditions so that the model does not fall out of context and is appropriate for the nature of the study.

An international survey on application of water quality models (Whitehead, 1984) has revealed that though models are being developed and used by planning, design and operational management agencies in many countries, many of them have been adopted for use by other countries also.

Table 7.1 presents a list of few of these widely acclaimed models in the field of river water quality. Table 7.2 summarises the characteristics and the major problem areas addressed by the above models.

Out of all these models, QUAL-II has been selected for its subsequent application in a few selected reaches of the Ganga Ecosystem for the following reasons : –

- Easy availability
- Reasonably good complexity and incorporation of a number of hydrological and water quality parameters, their interactions being quite capable of characterising the ecosystem.
- Proven world wide performance.

QUAL-II : Salient Features

Salient features of the selected model, QUAL-II are presented below (Roesner *et al.*, 1977) :

TABLE 7.1

Commonly Used Receiving Water Quality Models

Model Name	Commonly used Acronym	Originator
Chemical Reaction Models		
Analytically integrated		
Streeter-Phelps Dissolved Oxygen Equation	–	Indiana State Board of Health Bloomington, Indiana
Lumped Parameter Nutrient Budget Model	–	Center for Inland Waters, Canadian Fisheries Research Board, Burlington, Ontario
Long Term Phosphorus Balance Model	–	Battelle Pacific Northwest Labs, Richland, Washington
Steady-State Stream Network Model	SNSIM	US Environmental Protection Agency Region II, New York
Simplified Stream Model	SSM	Hydroscience, Inc., Westwood, New Jersey
Numerically Integrated		
Dissolved Oxygen Sag Model	DOSAG-1	Texas Water Development Board, Austin, Texas
Dissolved Oxygen Sag Model (revised version)	DOSAG-3	Water Resources Engineers, Austin, Texas
SCI. DOSAG Modification	DOSCI	Systems Control Inc., Palo Alto, California
Automatic Quality Model	AUTO - QUAL	U.S. Environmental Protection Agency
Receiving Water Model Module of SWMM	RECEIV SWMM	Water Resources Engineers, Walnut Creek, California
Receiving Water Model (modification)	RIVSCI	Systems Control Inc., Palo Alto, California
Receiving Water Model (modification)	WRECEV	Water Resources Engineers, Austin, Texas
Hydrocomp Hydrologic Simulation	HSP	Hydrocomp, Inc., Palo Alto, California
Ecologic Models (*All Numerically Integrated*)		
River Quality Model (QUAL-1 modification)	QUAL-II	Water Resources Engineers, Walnut Creek, California
Water Quality in Reservoir Systems	WQRR HECS	US Army Corps of Engineers, Hydrologic Engineering Center, Davis, California

Source : Whitehead P.G., 1984.

TABLE 7.2

Characteristics of Selected Receiving Water Quality Models

Model	Water Body Characteristics							Major Problems																								
	Water Body Type			Flow Conditions				Temperature			Salinity			Erosion & Sedimentation			Dissolved Oxygen				Eutro-phication			Toxic Substances				Biological Effects				
	Streams	Rivers	Lakes	Constant Streamflow	Variable Streamflow	Steady State Lake Levels	Variable Lake Levels	Ambient Variations	Waste Heat Inputs	Thermal Stratification	Natural Salt Sources	Irrigation Return Flows	Saltwater Intrusion	Bedload Transport	Suspended Solids Transport	Absorbed Residuals Transport	Carbonaceous Oxygen Demand Nonpoint Sources	Carbonaceous Oxygen Demand Point Sources	Nitrogenous Oxygen Demand	Instream Oxygen Demand	Nitrogen Kinetics	Phosphorus Kinetics	Minor Nutrients	Heavy Metals	Pesticides	Refractory & Synthetic Organics	Radioactive Material	Decomposers Inc. Coliform	Primary Producers	Zooplankton-Invertebrates	Fishes	Ecosystem-Level Indicators
SSM	*	*	*	*													*	*														
DOSAG-1	*	*		*													*	*	*													
DOSAG-3	*	*		*							*	*					*	*	*		*	*		*				*	*			
DOSC-I	*	*		*							*	*					*	*	*		*	*		*				*	*			
QUAL-I	*	*		*													*	*	*									*				
RECEIV	*	*	*	*	*	*	*						*				*	*	*		*	*	*	*	*	*	*	*				
RIVSCI	*	*		*	*			*	*				*				*	*	*		*	*	*	*				*	*			
WRECEV	*	*		*	*								*				*	*	*		*	*	*	*	*	**	**	*				
HSP	*	*	*	*	*	*	*	*	*	*			*				*	*	*		*	*	*	*	*	**	**	*	*	*		
QUAL-II	*	*		*				*	*		*	*			*		*	*	*		*	*		*	*	**	**	*	*			
WQRR	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*	*	*	*					*	*	*	*	

* applicable if treated as discrete particles.
** applicable as conservative constituent.

Source : Whitehead, P.G., 1984.

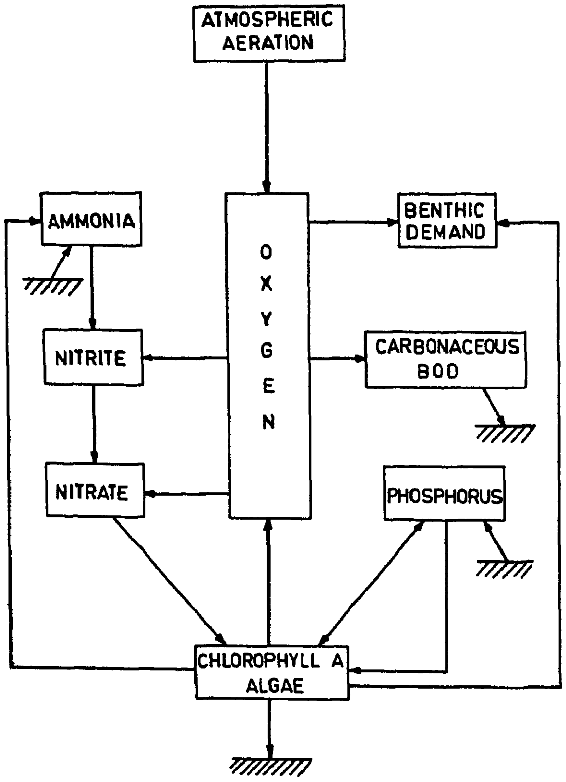

Figure 7.1 : Major Constituent Interactions
(*Source* : Roesner, L.A., *et al.*, 1977)

- It can simulate upto 13 water quality parameters in any combination desired by the user. Parameters which have been simulated are following :

(i) DO
(ii) B.O.D.
(iii) Temperature
(iv) Algae as chlorophyll-a
(v) Ammonia - N
(vi) Nitrite - N
(vii) Nitrate - N
(viii) Dissolved orthophoshate
(ix) Coliforms
(x) Arbitrary Non-conservative constituents
(xi)–(xiii) Conservative constituents

Major constituent interactions addressed are exhibited in Figure 7.1.

- Model is applicable to dendritic streams which are well mixed. It permits any branching, one dimensional stream system to be simulated, wherein the stream system is divided into reaches having uniform characteristics. Each reach is further divided in computational elements, around which the basic hydrologic / mass balance equations are formulated.

Figure 7.2 shows a typical reach and a computational element. A stream has been conceptualized as a string of completely mixed reactors. The detailed schematic diagram of a hypothetical river system is presented in Figure 7.3.

- Hydraulically, it is limited to simulation of time periods during which stream flow in the river basin is essentially constant.
- It can be operated as a steady state or a dynamic model. Dynamic operation makes possible to study the effect of diurnal variations in meteorological data on water quality (primarily dissolved oxygen and temperature).
- It is structured as one main programme QUAL-II supported by 23 subroutines. Figure 7.4 exhibits the functional relationship between main program and the subroutines.

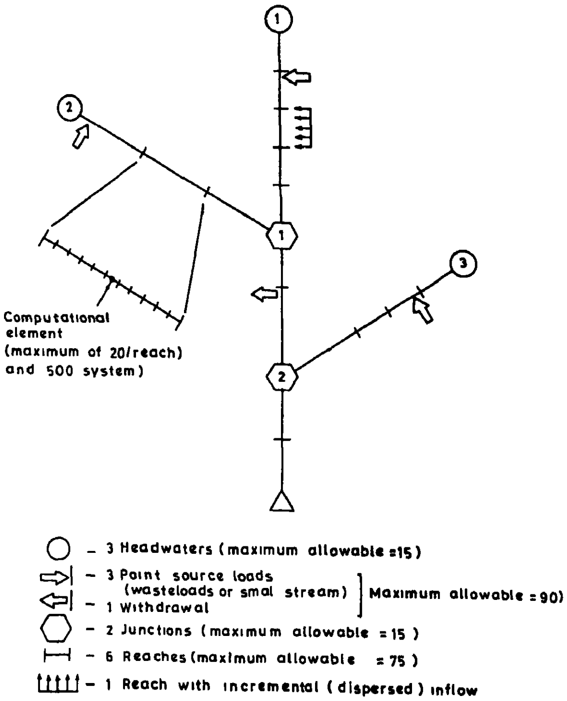
1
2
3
1
2
Computational element (maximum of 20/reach) and 500 system)
○ – 3 Headwaters (maximum allowable =15)
⇨| – 3 Point source loads (wasteloads or smal stream)
⇦| – 1 Withdrawal
Maximum allowable = 90)
⬡ – 2 Junctions (maximum allowable = 15)
├─┤ – 6 Reaches (maximum allowable = 75)
↑↑↑↑ – 1 Reach with incremental (dispersed) inflow

Figure 7.2 : A Schematic Diagram of a Hypothetical Stream System
(*Source* : User's manual for stream quality model, QUAL-II, EPA)

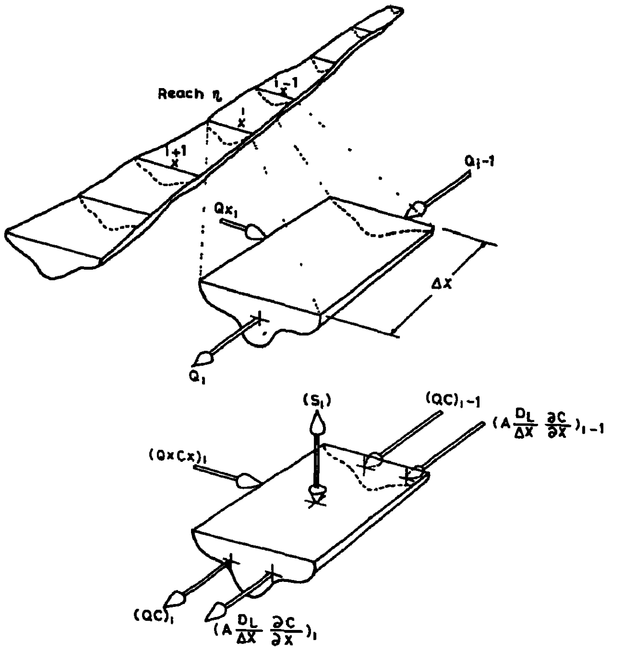
Reach n
i-1
i
i+1
Q_{i-1}
Qx_i
Δx
Q_i
(S_i)
$(QC)_{i-1}$
$(A\frac{D_L}{\Delta x}\frac{\partial c}{\partial x})_{i-1}$
$(QxCx)_i$
$(QC)_i$
$(A\frac{D_L}{\Delta x}\frac{\partial c}{\partial x})_i$

Figure 7.3 : Discretized Stream System
(*Source* : Roesner, L.A.,[1] *et al.*, 1977)

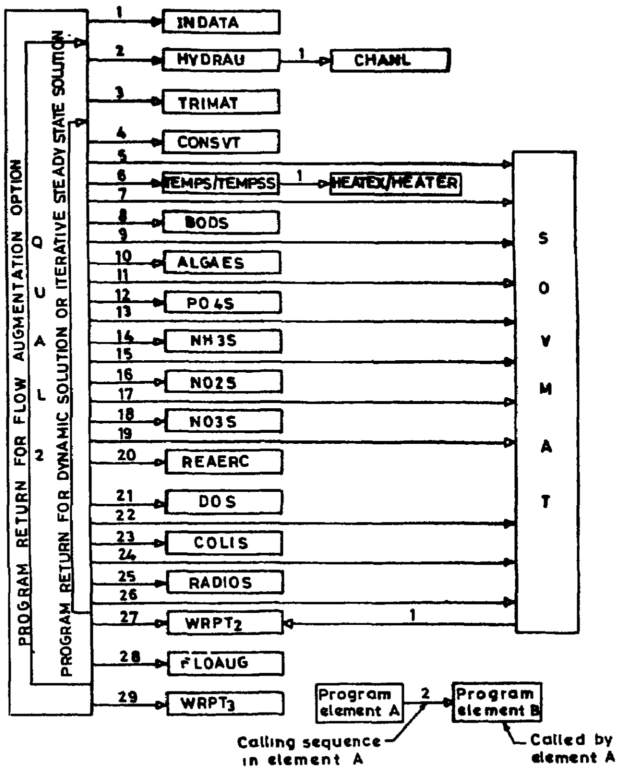

Figure 7.4 : General Structure of QUAL - II
(*Source* : Roesner, L.A., *et al.*, 1977)

The mathematical equations solved by QUAL-II are presented in Table 7.3. Various terms, coefficients and input parameters used in these equations are briefly described below :

Ax = cross sectional area (L^2)

D_L = longitudinal dispersion coefficient (L^2/T)

v = mean velocity (L/T)

S = source or sink term for each parameter (M/T)

μ = local specific growth rate of algae(l/T)

$$\mu = \mu_{\max} \frac{N_3}{N_3+K_N} \cdot \frac{P}{P+K_P} \cdot \frac{1}{\lambda_d} \ln \frac{K_L+L}{K_L+L\,e^{-\lambda d}}$$

$\mu_{\max}$ = maximum specific growth rate of algae (l/T)

K_N = nitrogen half-saturation constant for algal growth (M/L^3)

K_P = phosphorus half-saturation constant for algal growth (M/L^3)

K_L = light half-saturation constant for algal growth (Langleys/min)

λ_d = light extinction coefficient

ρ = local respiration rate for algae (l/T)

σ_1 = local settling rate for algae (L/T)

d = average depth (L)

α_1 = fraction of algal biomass which is N

β_1 = rate constant for biological oxidation of Ammonia Nitrite (l/ T)

α_3 = oxygen production per unit of algal growth

β_2 = rate constant for biological oxidation of Nitrite Nitrate(l/T)

α_2 = fraction of algal biomass which is P

σ_2 = Benthos source rate for phosphorus (M/LT)

K_1 = carbonaceous BOD decay rate (l/T)

K_3 = carbonaccons BOD sink rate (l/T)

K_2 = re-aeration rate (l/T)

Φ_* = saturation concentration of D.O. (M/L^3)

α_4 = oxygen uptake per unit of algae respired

α_5 = oxygen uptake per unit of NH_3 oxidation

α_6 = oxygen uptake per unit of NO_2 oxidation

K_5 = coliform die-off rate (l/T)

K_6 = arbitrary nonconservative decay rate (l/T)

TABLE 7.3

Summary of Differential Equations to be solved by QUAL-II

Conservative mineral (c)	$\frac{\partial c}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial c}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uc)}{A_{\mathrm{x}}\, \partial x} + \frac{S_c}{A_{\mathrm{x}}\, dx}$
Algae (A)	$\frac{\partial A}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial A}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uA)}{A_{\mathrm{x}}\, \partial x} + \frac{S_{\mathrm{A}}}{A_{\mathrm{x}}\, dx} + \left(\mu - \rho - \frac{\sigma_1}{\alpha}\right) A$
Ammonia nitrogen (N_1)	$\frac{\partial N_1}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial N_1}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uN_1)}{A_{\mathrm{x}}\, \partial x} + \frac{S_{N_1}}{A_{\mathrm{x}}\, dx} + \left(\alpha_1 \rho A - \beta_1 N_1 + \frac{\alpha_3}{A_{\mathrm{x}}}\right)$
Nitrite nitrogen (N_2)	$\frac{\partial N_2}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial N_2}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uN_2)}{A_{\mathrm{x}}\, \partial x} + \frac{S_{\mathrm{N}_2}}{A_{\mathrm{x}}\, dx} + (\beta_1 N_1 - \beta_2 N_2)$
Nitrate nitrogen (N_3)	$\frac{\partial N_3}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial N_3}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uN_3)}{A_{\mathrm{x}}\, \partial x} + \frac{S_{\mathrm{N}_3}}{A_{\mathrm{x}}\, dx} + (\beta_2 N_2 - \alpha_1 \mu A)$
Dissolved orthophosphate (P)	$\frac{\partial P}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial P}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uP)}{A_{\mathrm{x}}\, \partial x} + \frac{S_{\mathrm{P}}}{A_{\mathrm{x}}\, dx} + \left(\alpha_2\, (\rho - \mu) A - \frac{\sigma_2}{A_{\mathrm{x}}}\right)$
Biochemical oxygen demand (L)	$\frac{\partial L}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial L}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uL)}{A_{\mathrm{x}}\, \partial x} + \frac{S_{\mathrm{L}}}{A_{\mathrm{x}}\, dx} - (K_1 + K_3)\, L$
Dissolved oxygen (ϕ)	$\frac{\partial \phi}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial \phi}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, u\phi)}{A_{\mathrm{x}}\, \partial x} + \frac{S_\phi}{A_{\mathrm{x}}\, dx}$ $+ \left[K_2\, (\phi^* - \phi) + (\alpha_3 \mu - \alpha_4 \rho) A - K_1 L - \frac{K_4}{A_{\mathrm{x}}} - \alpha_5 \beta_1 N_1 - \alpha_6 \beta_2 N_2\right]$
Coliform (F)	$\frac{\partial F}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial F}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uF)}{A_{\mathrm{x}}\, \partial x} - \frac{S_{\mathrm{F}}}{A_{\mathrm{x}}\, dx} - K_5 F$
Arbitrary Nonconservative (R)	$\frac{\partial R}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial R}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uR)}{A_{\mathrm{x}}\, \partial x} - \frac{S_{\mathrm{R}}}{A_{\mathrm{x}}\, dx} - K_6 R$
Temperature (T)	$\frac{\partial T}{\partial t} = \frac{\partial\left(A_{\mathrm{x}} D_{\mathrm{L}} \frac{\partial T}{\partial x}\right)}{A_{\mathrm{x}}\, \partial x} - \frac{\partial (A_{\mathrm{x}}\, uT)}{A_{\mathrm{x}}\, \partial x} + \frac{H_{\mathrm{N}}}{\rho c d}$

Extensive application of QUAL - II and of its modified versions has been reported in several contexts in the literature. A few are presented below:

(a) Waste load allocation and general river water quality status identification studies (Walker, *et al*, 1983 ; Sinha, 1981).

(b) Critical relative evaluation of several commonly used models in terms of :

  (i) their validity under increasingly strict calibration and verification criteria, and

  (ii) prediction ability for conditions of varying complexity. (Whitemore, *et al.*, 1982)

(c) Simulation of isolated parameters (Rowney and Roesner, 1982).

(d) Evaluation of impact of the wastewater treatment plant on the river to which its effluents are being discharged (INCOG, 1984).

Model Application

The first step is the stretch identification within the system for the intended model application, followed by its fragmentation in various components as exhibited in Figure 7.4. A stretch of approximately 75km around Anupshahar and another of approximately 10km around Rishikesh were identified in the proposed study, a minimum of 5 sampling stations planned on the river within the stipulated length of each stretch. Intensive field data collection program has been conducted during February – March 1988, a period exhibiting low flow conditions, reasonably satisfactory for modelling application.

The second step is the model parameter evaluation. Following parameters have been measured in the field or laboratory.

Water Quality

(1) Water Temperature
(2) DO
(3) B O D
(4) Total Dissolved Solids (Conservative Mineral)
(5) Algae or Chlorophyll-a
(6) Phosphates
(7) Ammonia-N
(8) Nitrite-N
(9) Nitrate-N
(10) MPN Coliforms
(11) Faecal Coliforms (Arbitrary Nonconservative)
(12) Deoxygenation Coefficient
(13) Coliform decay rate
(14) Light Extinction Coefficient
(15) Photosynthesis – Respiration Rate

Hydrology

(16) Stream Discharge
(17) Stream Velocity
(18) Cross-section width and depth

Climatology

(19) Solar Radiation
(20) Cloudiness
(21) Dry Bulb Temperature
(22) Wet Bulb Temperature
(23) Barometric Pressure
(24) Wind Speed.

Calibration and verification, constituting the next step, are attempted to find out how the model imitates the real world. In the calibration phase, mathematical equations are solved keeping the values of known parameters and adjusting the values of unknown parameters within a reasonable anticipated range such that the computed results match the observed data as per the specifications of the worker. Once calibrated, the model may be run for a separate set of input data to achieve fresh results and if it shows a reasonably good match with the observed data, declare the model as verified. Ideally, a model is declared as fit for any further predictive application only after successful calibration and verification. The idea behind selecting two stretches under seemingly different set of conditions in the present case has been to propose the use of one of these for calibration and the other for verification of the said model.

A very important step in the modelling exercise is Sensitivity Analysis which is explained as (Hall and Day 1978) "Means of determining how important the different model components and coefficients are to the model output and aids the researchers in understanding which components should be measured most carefully".

In practice, sensitivity is examined by perturbing one parameter from a given value by a constant amount (i.e ± 50 per cent) while the others are kept constant (Whitemore, *et al.*, 1982). This perturbation amount usually represents the amount of uncertainty or error associated with each parameter importance of which on the output yields very significant information. It is proposed to evaluate the sensitivity of various major reaction rates and the hydrologic parameters in this study.

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8

Instrumentation for Pollution Monitoring of Hugli Estuary

P. SOM

The objective of the project was to design and develop an Instrumentation system for in-situ sensing, monitoring, recording and transmitting by telemetry for processing and storage of the essential water quality parameters : electrical conductivity (EC), hydrogen ion concentration (*p*H), temperature ° C, dissolved oxygen (DO), and velocity of surface, water bodies with indigenously fabricated hardwares as far as practicable. During the tenure of the project it was possible to complete the following studies :

(i) development of sensors and circuits for EC, *p*H, temp.°C, DO and their packaging. The velocity monitoring system could not be developed;
(ii) calibration of analog signals (voltage) for measuring the parameters;
(iii) hardwares and softwares for data acquisition, transmission, reception and storage;

Pursuant to the objectives delineated earlier, the functional facets for the project embraced :

(i) to procure, test and assemble the sensors (transducers) for EC, *p*H, temperature and DO to suit field requirements ;
(ii) to design, develop and fabricate necessary circuits of adequate sensitivity and capable of providing a desired minimum output signal at minimal conditions in the water body with sensors as stated above ;
(iii) to calibrate the signals against selected ranges of the water quality parameters compatible with field conditions ;
(iv) packaging ;
(v) development of multichannel data input system of the microprocessing unit ;
(vi) transmission and reception for centralised processing.

The sensors for EC, *p*H, DO and temperature were made ready for field use. The principles of the sensors used are given in Table 8.1.

Sensors are based on the basic principles of converting water quality parameters into voltage signals.

TABLE 8.1

Sensors Used for Developing the Instrumentation Complex

Parameter	Type	Source
Temperature	Thermistor based	Developed by the Project Investigators
*p*H	Combined glass electrode	Indian manufacturers
Electrical conductivity	Platinized-platinum electrode	
Dissolved Oxygen	Gold silver electrode with gas permeable membrane	

Profs D. C. Patranobis, D.K. Basu, Rana Datta Gupta, Santimoy Niyogi and Dr. S.K. Bhowal were Co-Investigators. The study was assisted by Subhankar Bandhopadhyay (Research Scientist, Sept.27, 1984 to Aug.18, 1985 and subsequently as Hon .R A), Smt Aparna Mukhopadhyay (Res.Scientist, July 1985 to Jan. 18, 1987), Uttam Kumar Bhattacharya (Res.Scientist, April 1, 1984 to Sept.30, 1987) and Alakananda Sen Gupta (SRF, June 1, 1984 to Jan.31, 1987 and April 1, 1987 to Sept. 30, 1987).

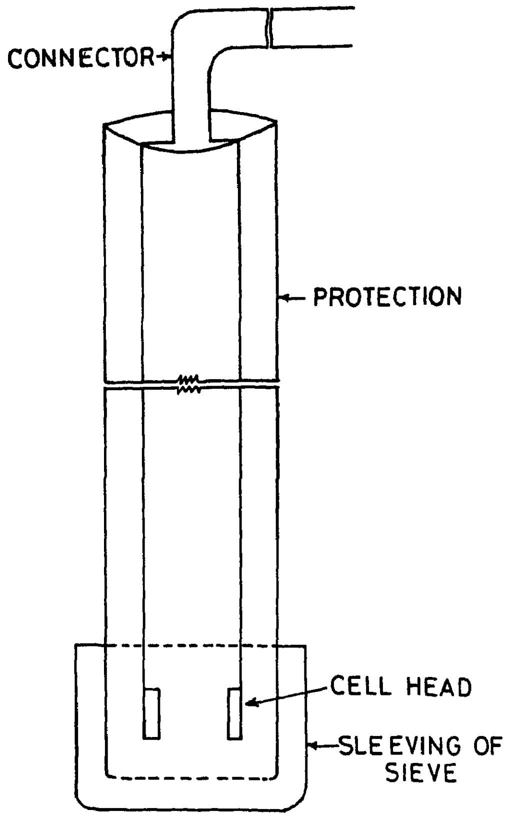

Figure 8.1 : Probe in General
(Protection of cell)

Except for the temperature and velocity sensors, the others as used here produce voltage, E, according to the ionic balance given by :

$$E = \left(\frac{RT}{B}\right) Log_e A \qquad \ldots\ \ldots\ (1)$$

where,

A is the parameter being measured;
B is an implicit constant ;
R is a constant ; and
T is the ambient temperature ° K.

For thermistor type temperature sensors used here, the output - input relation is given by :

$$E_T = E_0 \quad \exp. \frac{B}{T} \qquad \ldots\ \ldots\ (2)$$

where, B is a constant and T is the temperature ° K.

E_0 is the output at the reference temperature ° K.

The additional constraint lies in the sensors' adaptation to the field conditions. By way of example, the conductivity sensor (cell) may be considered. It usually has a glass casing and, therefore, vulnerable to shock loads of even very small magnitude. It requires shielding but must have the measuring cell volume open to the flowing water. A protection on the entire cell body with a sleeve and a cap at the bottom with sieve type structure is one kind of solution for such situation. Figure 8.1 shows such a type of modification of cell protection. Similar protection may be provided for *p*H and DO sensors.

The thermistor-based temperature probe developed for the project is of different type. It uses a bead type glass casement thermistor. The encased bead is then housed in a 3 mm diam. tubing with the lead end at the bottom side and the terminals on the top. The ends are sealed and the connecting terminals are brought out from the top and finally water tight sealing is made at the top. The probe looks like the one shown in Figure 8.2 (Thermistor Probe).

The *p*H, EC and DO probes were procured from Indian manufacturers, tested at the University laboratories and assembled to suit the specific field conditions.

While development of sensors had been, by and large backed by the commercially available systems barring the temperature probe, the circuits that were

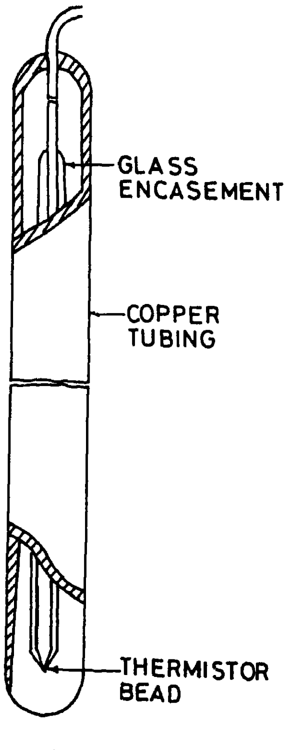

Figure 8.2 : Thermistor Probe

available did not satisfy the project requirement. This was mainly because most of the commercial circuits were for off-line laboratory measurements with varying ranges attainable by manual switching, ambient conditions compensation also being attainable by switching manually. Moreover, these were heavy and unsuitable for field conditions.

It, therefore, became necessary to design and develop new circuits that have adequate sensitivity for proving an optimum signal decided upon by the requirement of the nominal condition of the transmission system, while the commercial circuits developed were essentially suitable for further processing of the signals.

Further, the circuit reliability need be considered in such a field condition as is mostly governed by the component reliability.

For conductivity measurement, the sensor (cell) must be provided with AC supply to avoid polarisation. If the frequency of supply is below about 400 Hz, the possibility of interference due to white noise exists. A frequency from 600 Hz to 1000 Hz is a good choice. Higher frequency is also prohibitive because of stray effects which may mar the advantages.

It consists of a Wien bridge oscillator of theoretically designed frequency of

$$f = 0.5 \times (10^3 / 0.15) \text{ Hz} = \frac{6670}{2} \text{ Hz (approx.)}$$

The output is kept variable with a potential divider which is, however, made possible because of a succeeding gain amplifier stage with high input impedance level. The probe connects this amplifier with the final detector amplifier. The adjustability is kept only at a resistance at the output terminal of the oscillator for convenience.

The output impedance of the *p*H electrode assembly provides considerable deterrent forces in designing a proper amplifier stage for deriving the required voltage output. The circuit was designed with a Chopper stabilised input stage for avoiding the variable coupling of sensors. The second stage is the variable gain stage and its gain is set by the gain-set potentiometer. Compensation is also provided in the scheme.

For temperature as mentioned earlier, a thermistor probe housed in a sealed copper tubing designed and fabricated and a corresponding measuring circuit is developed to suit the probe and the requirement.

The circuit for dissolved oxygen measurement has to give adequate protection for sensor and compensation for ambient fluctuation.

Since steady stabilized supply is essential for the operation of the circuits, a scheme for the supply (dual) is also made and the hardwares built for the purpose.

The outputs obtained from the circuits of the sensor measurement system are now passed on to A/D converters for digitising to a mode compatible to the digital signal processing system, the details of which are given subsequently.

The *p*H sensor has been calibrated by using standard buffer tablets of *p*H, 4.0, 7.0 and 9.0. For intermediate *p*H values, standard solutions were prepared in the laboratory. The known *p*H buffer solutions as above were carefully checked with a sensitive *p*H meter and then signal voltages shown by the series of known *p*H buffer solutions with the presently developed measuring system were recorded.

For calibration of the conductivity sensor, standard KCl solutions of known conductivities were prepared, checked in a sensitive conductivity meter, and then the signal voltages as given by the developed system were noted.

The DO sensor consists of a gas permeable membrane. Diffusion of oxygen through the above membrane is dependent on the stirring rate. Thus, varying the stirring rate resulted in varying outputs from the DO measuring system.

Since the possible stirring rate expected to be produced by the Hugli estuary water could not be simulated by manual/automatic means in the laboratory, the calibration results for DO to be used in the system are not provided.

For temperature, water samples of different known temperatures were obtained by either cooling or heating the samples in a thermostatic water bath and recording the signal voltages.

During calibration, the range of values of the parameters were carefully selected to cover the variations commonly observed in surface water bodies. It should be emphasized that in this tropical country there is a likelihood of variation of river water temperature between 10° C and 40° C over the year. The circuits are designed for a nominal temperature of 25° C with a possible variation of ± 10%. Experiments, however, were conducted for obtaining the calibrated results continuously over a week at two different seasons and the results were found to be consistent.

The long term stability of the circuit performance depends on the stability of components used. Many of the components used in the circuits including the integrated chips were procured from the available source without having any knowledge of their stability or mean time failure (MTF). Their operational reliability was thus unknown and could not be ascertained because of lack of required data. The system performance is, therefore, open to tolerance or erratic behaviour because of the uncertainty in the performance of the components.

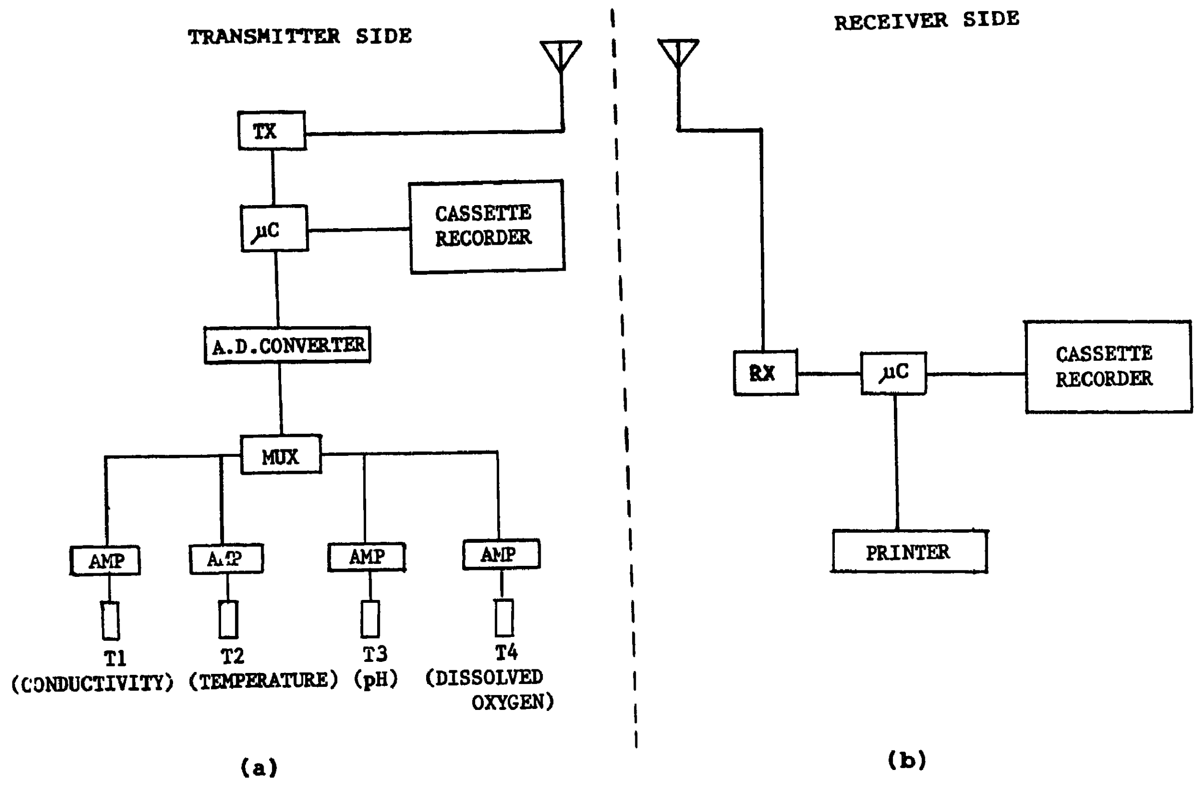

Figure 8.3 : Transmitting and Receiving Sides

The calibration data for *p*H, EC and temperature are presented in Table 8.2.

TABLE 8.2

Calibration Data

(i) *Hydrogen Ion Concentration* (*p*H)							
*p*H	4.0	5.0	6.0	7.0	8.0	9.15	
Signal, Volts	5.06	4.32	3.67	2.91	2.24	1.37	
(ii) *Electrical Conductivity* (EC)							
EC Micro-mhos/cm at 25°C	147	423	718	1086	1413		
Signal, Volts	0.79	1.70	2.70	3.66	5.06		
(iii) *Temperature* (°C)							
Temperature°C	20	23	25	29.5	35	37	44
Signal, Volts	0.80	1.04	1.11	1.46	1.8	2.13	2.51

The data metering system consists of two sections :

1. transmitting section
2. receiving section.

These are physically separate from each other as shown in Figure 8.3

The transmitting section consists of the following parts :

(i) SENSORS

(ii) A/D CONVERTER – Converts electrical signals from the sensors into corresponding digital values.

(iii) MICROCOMPUTERS – It is used to monitor the different channels of the sensors periodically with a programmable interval of time and to read the same to the transmitter in a specified format. It may also store the same in a cassette as a back up which may be required in case of transmitter/receiver failure.

(iv) TRANSRECEIVER – It comprises two stages. Gadgets belonging to the first stage is kept at the point of monitoring and is of lower communication range (2 km). It transmits the data processed by the microcomputer in an FM technique to the second stage of higher communication range (25 km), which is used to receive the information from the first stage and transmit it further to the remote place, e.g. laboratory, data collection centre etc. The second stage transmission is not developed. The allotted frequencies are 79.4 and 84.4 MHz.

The receiving section consists of the following components :

(i) TRANSRECEIVER – It receives the information transmitted and feeds it to the microcomputer ;

(ii) MICROCOMPUTER – It polls for a pre-specified pattern which precedes the data set during transmission. On receipt of the said pattern (leader), it begins to store the incoming data in the RAM. The stored information may also be printed for hard copy. The received data are also stored in the cassette recorded for future reference. However the interface between the micro computer and the host system for final processing has not been developed.

Conclusions

(i) The development of circuits, except for velocity, are completed for *p*H, dissolved oxygen (DO), electrical conductivity (EC), and temperature (°C) from indigenously available components.

(ii) The reliability of these components can only be estimated by conducting experiments with these circuits over a prolonged period of around one year in a real life situation. The present exercise is terminated at the laboratory bench-scale level.

(iii) Similarly, the transmission and receiving of constantly monitored data at two stages – from the floating buoy to the shore based antenna and from the antenna to the State Laboratory (Jadavpur University) – will need about a year's time to study the performance of the prototype set up.

(iv) To the best of our knowledge, there is no available bench mark system in this region incorporating the various components of our research work for comparison and evaluation of our system both performance wise and reliability wise. If such a system is available the comparison should be done. For this there is a need to explore the market.

(v) To evaluate the real life performance of the system by taking an exercise in the Hugli Estuary at a suitable point for a period of around one and a half years we should conduct pilot study in collaboration with an entrepreneur to develop the instrumentation kit, and the telemetering system for commercial production.

9

Establishment of a Ganga Research Station in the Campus of Banaras Hindu University

U. K. CHOUDHARY

The Ganga model laboratory is a part of the studies undertaken by the Banaras Hindu University. This laboratory was set up to investigate the following aspects of the river:

(i) The Assessment of Pollutants – quantity and quality reaching the river body through surface media.
(ii) Effluent dispersion in the river.
(iii) Ground water quality and its flow condition.
(iv) River geometry and its flow behaviour.
(v) Variation in river water surface (RL) and sediment load.
(vi) The methodology for the assessment and management of pollution load with the help of the Ganga laboratory physical model.

All these activities were confined to the Varanasi region. The major nalahs viz., Assinala, Shiwala ghat drain, Chauki ghat drain, R.P. ghat drain and Raj ghat nala were monitored for quality and quantity once in every month. The measurements indicated that the minimum discharge of about 100 mld occurred in the month of June when compared to the average total discharge of about 117 mld.

The longitudinal and transverse dispersion of four physico-chemical parameters: DO, conductivity, *p*H and temperature around the discharge points of the five major nalahs, were studied. The ground water quality and flow pattern were studied in 25 observation wells located around the above-mentioned five different nalahs/ghats. The physico-chemical parameters of the ground water were observed not only to be varying from location to location but also from season to season.

The river flow behaviour was assessed during the months of May and June in the years 1986 and 1987. Several reversal flow zones were observed along the banks wherein the mixing of water with the river water was found to be very poor.

For assessment and management of pollution, a physical laboratory model was constructed to scale for a stretch of 30 kms, for investigating water flow and dilution factors on geometrical, kinematic, dynamic similarities. The model has a total work area of 80,000 sq. ft and consists of: –

(a) river model platform, 60,000 sq.ft.
(b) Inlet channel (150′ × 3.25′ × 2′)
(c) Sediment settling channel (150′ × 3.25′ × 3′)
(d) Recirculating channel (385′ × 3.25′ × 2′)
(e) Discharge measuring tank (20′ × 12′ × 7′)
(f) Gangotri tank (11,000 cubic ft)
(g) A laboratory housing instruments and computer for simulation modelling.

This physical model can be used for studying :-

(i) Quantity and quality of pollutants discharged into the river or those reaching river through surface drains and ground water.
(ii) Quantification of pollutants before or after treatment which can be safely discharged into the river on principles of mixing.
(iii) Interaction of pollutants with river water and the zone of dispersion.
(iv) Assessment of flood damage.

10

Biological Profile of the Ganga : Phytoplankton

S. SREENIVASAPRASAD

The phytoplankton profile of the Ganga excepting for the stretch of Kannauj to Shuklaganj is presented in this Chapter*. The study is based on investigations conducted by the University of Garhwal, Roorkee University, Banaras Hindu University, Patna University, Rajendra University of Agricultural Sciences, Bhagalpur University, Kalyani University, Bidhan Chandra Krishi Vidyalaya and Calcutta University. Samples for qualitative examination and quantitative determinations were collected from different cross-sections of the river by plankton net (bolting silk) and were preserved in 4 per cent formalin.

Determination of phytoplankton density of an aquatic system often poses problems, in view of the variety of configurations of the constituent organisms. The total cell count method, and determination of volume of individuals of each species per volume of water would yield an accurate assessment of the biomass, but are time consuming and tedious. The natural unit count (Ingram and Palmer, 1952) adopted in the present investigation is the most easily used system. The phytoplankton density is expressed as unit per litre (u/l) representing an organism, either unicellular or a natural colony. For the enumeration, various counting cells or chambers, that limit the volume and area to enable ready calculation of the population, are available. The Lackey drop (micro-transect) method followed presently (Lackey, 1938; Edmondson, 1974) is similar to the Sedgwick – Rafter strip count, simple and of considerable accuracy, particularly with samples containing dense plankton population.

Phytoplankton Density

The upper stretch : Between Gangotri and Rishikesh, maximum phytoplankton density (8223 u/l) was recorded in winter at Gangotri (Bhagirathi) and minimum (13 u/l) in monsoon months. Among the planktonic population, diatoms were predominant (1680 u/l) in winter and relatively lesser (592 u/l) in summer. Likewise, density of green algae was 110 u/l in winter and 35 u/l in summer. Few blue-greens in winter alone and some red algae were also spotted. Between Badrinath and Rishikesh, the phytoplankton density was optimum (8720 u/l) during summer and minimum (111 u/l) in the rainy season. A similar trend in the phytoplankton population was observed between Rishikesh and Narora (7439 and 100 u/l respectively).

The annual average of total phytoplankton for the stretch from Rishikesh to Garhmukteshwar was maximum (4258 u/l) near Bijnor barrage and minimum (334 u/l) at Shyampurkhadir. The plankton population at Haridwar (based on four sampling points) was low, presumably due to the adverse impact of human activity (mainly pilgrims bathing). The plankton population was maximum during summer and minimum during rainy season. Altogether 100 algal forms were recorded in this zone. Members of the Chlorophyceae were dominant followed by Cyanophyceae, Dinophyceae, Cryptophyceae, Euglenophyceae and Crysophyceae.

The middle stretch : Phytoplankton population was very high between Mirzapur and Ballia. Maximum Phytoplankton density (8,30,000 u/l) was from the upstream of Varanasi during summer and minimum (51,200 u/l) was in Khandwa Nala, Mirzapur during the rainy season. In this region 100 algal species were recorded.

From Buxar to Barh, a stretch of 240 km, the phytoplankton density showed a sharp decline (4 – 296 u/l) when compared to the Mirzapur-Ballia region. A total of 26 algal forms were recorded in this stretch, of which 18 belonged to Chlorophyceae, 6 to Cyanophyceae and 2 to Bacillariophyceae. The dominance of chlorophycean members was observed year-round with highest population density during summer followed by winter and monsoon. Clear-cut seasonal variation in the plankton density and the influence of physico-chemical characteristics of the water body were recorded. Plankton density increased gradually with rise in water temperature from January to May. The extended solar radiation and richer nutritional status during summer appear to favour the increase in the population density. On the other hand, during monsoon, light penetration is low resulting in less primary production and lesser number of phytoplankton. From October onwards, as the water transparency increases, the standing stock of phytoplankton starts picking up. Further, the algal members, particularly Chlorococcales seem to prefer situations rich in oxygen and nitrogenous matter.

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* See Chapter 23.

Between Barh and Sultanganj (140 km stretch), the phytoplankton density showed an upward swing with 42,000 - 90,000 u/l during winter, 11,800 - 42,000 u/l in summer and an average of 1,40,000 u/l in the rainy season. Altogether 61 algal species were identified in this zone out of which 23 belonged to Cyanophyceae, 13 to Chlorophyceae, 22 to Bacillariophyceae, 2 to Xanthophyceae and 1 to Euglenophyceae.

Based on depth profile and cross-sectional studies at different sites of the river, 182 algal species were recorded in the stretch between Munger and Farakka. In this region, Chlorophyceae dominated year-round followed by Cyanophyceae and Bacillariophyceae. Chlorophyceae and Cynophyceae were abundant in summer whereas diatoms were more during the rainy season. The standing stock of phytoplankton ranged from 1330 to 2986 u/l during summer, 19 - 589 u/l in the rainy season and 240 - 1589 u/l in winter. A sharp fall was registered in the density and diversity of phytoplankton during the rainy season at all the sites.

The lower stretch : Between Berhampur and Katwa, maximum phytoplankton density (8200 u/l) was recorded in the summer and minimum (100 u/l) in the rainy season. The plankton density varied at different sites and two growth peaks were observed, one in March and another in May. A total of 44 algal species were recorded in this region, of which 10 belonged to Chlorophyceae, 14 to Cyanophyceae, 17 to Bacillariophyceae and one each to Rhodophyceae and Xanthophyceae. Diatoms– *Cymbella*, *Synedra* and *Melosira* - among unicellular forms, and *Spirogyra* and

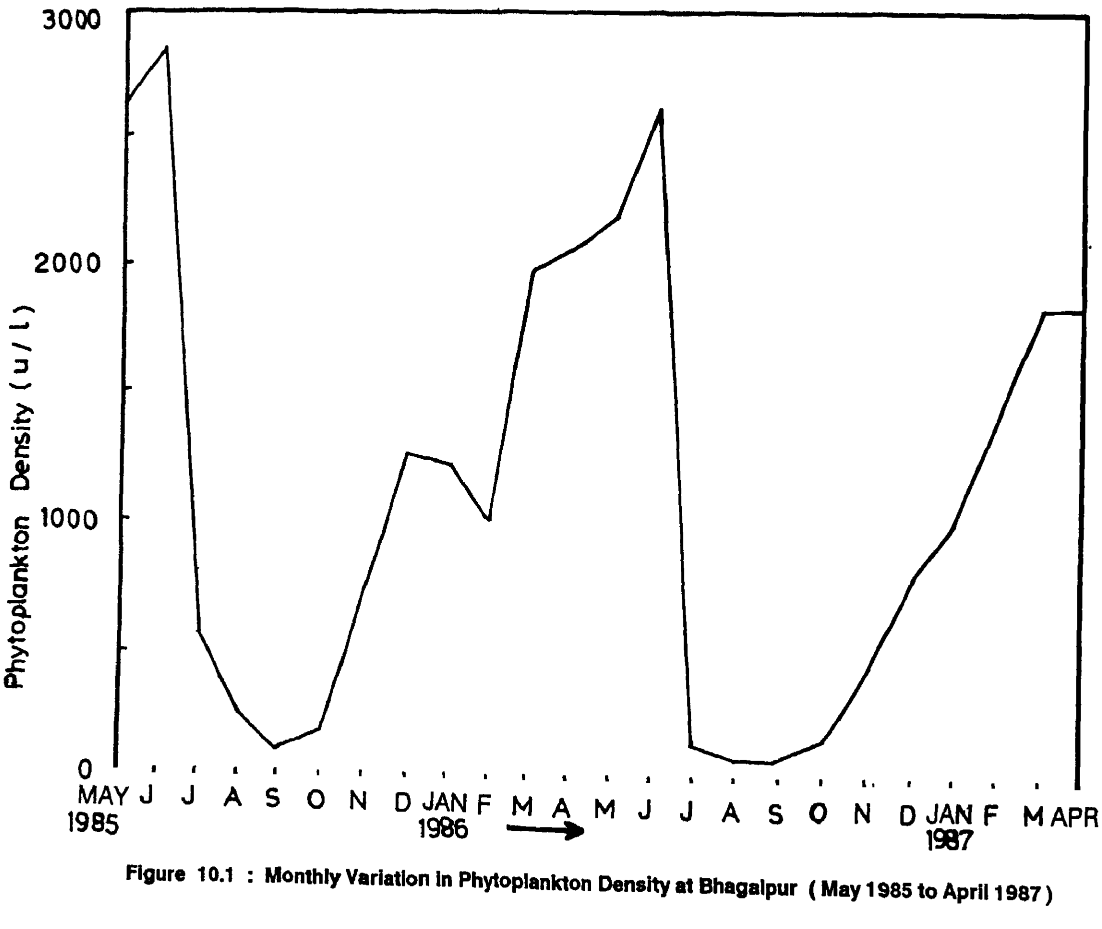

Figure 10.1 : Monthly Variation in Phytoplankton Density at Bhagalpur (May 1985 to April 1987)

TABLE 10.1

Algae Present in Different Stretches of the River Ganga

Name of Algae	Upper stretch (Gangotri/Badrinath to Garhmukteshwar)	Middle stretch (Mirzapur to Farakka)	Lower stretch (Berhampur to Bally)
1	2	3	4
CYANOPHYCEAE			
Anabaena circularis	A	P	A
A. cylindrica	A	P	A
A. fertilissima	A	P	A
A. laxa	A	P	A
A. orientalis	A	P	A
A. variabilis	P	A	A
Anabaena sp.	P	P	P
Anabaenopsis arnoldi	A	P	A
Anacystis sp.	P	A	A
Aphanizomenon sp.	A	A	P
Aphanocapsa montana	A	P	A
Aphanothece microscopica	A	P	A
A. pallida	A	P	A
Aphanothece sp.	A	P	A
Arthrospira jenneri	A	P	A
A. tenuis	A	P	A
Arthrospira sp.	P	P	A
Aulosira fertilissima	A	P	A
Calothrix elenkinii	A	P	A
C. fusca	A	P	A
Calothrix sp.	P	A	A
Chrooccidiopsis indica	P	A	A
Chroococcus minor	A	P	A
C. turgidus	A	P	A
Crinalium sp.	A	P	A
Cylindrospermum licheniforme	A	P	A
Cylindrospermum sp.	P	A	A
Eucapsis sp.	A	A	P
Gloeocapsa quatemata	P	P	A
Gloeocapsa sp.	A	P	A
Gloeotrichia echinulata	A	P	A
Gloeotrichia sp.	P	A	A
Hapalosiphon sp.	A	A	P
Johannesbaptistia sp.	A	P	A
Lyngbya gracilis	A	P	A
L. hieronymusii	A	P	A
L. lagerheimii	A	P	A
L. limnetica	A	P	A

A = Absent ; P = Present *(Contd.)*

TABLE 10.1 - *Contd.*

1	2	3	4
L. magnifica	P	P	P
L. subconfervoides	A	P	A
Lyngbya sp.	P	P	P
Mastigocladus sp.	P	A	A
Merismopedia elegans	A	P	A
M. glauca	A	P	A
M. minima	A	P	A
M. punctata	A	P	A
Microcoleus chthonoplastes	A	P	A
Microcoleus sp.	A	P	A
Microcystis aeruginosa	A	P	P
M. flos-aquae	A	A	P
M. marginata	A	P	A
M. protocystis	P	A	A
Myxosarcina sp.	P	A	A
Nodularia spumigena	A	P	A
Nodularia sp.	P	P	A
Nostoc linckia	A	P	A
Nostoc sp.	P	P	P
Oscillatoria chilkensis	A	P	A
O. chlorina	A	P	A
O. corallinae	A	P	A
O. formosa	A	P	A
O. limosa	A	P	A
O. ornata	A	P	A
O. princeps	A	P	A
O. proteus	A	P	A
O. raciborskii	A	P	A
O. subbrevis	A	P	A
O. tanganyikae	A	P	A
O. tenuis	A	P	A
O. willei	A	P	A
Oscillatoria sp.	P	P	P
Phormidium calcicola	A	P	A
P. inundatum	A	P	A
P. purpurscens	A	P	A
P. uncinatum	A	P	A
Phormidium sp.	P	P	P
Pseudanabaena schmidlei	A	P	A
Raphidiopsis curvata	A	P	A
Rivularia aquatica	P	P	A
Schizothrix sp.	P	A	A
Spirulina gigantea	A	P	A

A = Absent ; P = Present

(Contd.)

TABLE 10.1 – *Contd*.

1	2	3	4
S. major	A	P	P
S. meneghiniana	A	P	A
S. subsalsa	A	P	A
Symploca sp.	P	A	A
Synechococcus elongatus	A	P	A
Synechocystis aquatilis	A	P	A
Synechocystis sp.	P	A	A
Tolypothrix sp.	P	A	P
Trichodesmium sp.	A	A	P
CHLOROPHYCEAE			
Acanthosphaera sp.	P	A	A
Actinastrum hantzschii	A	P	A
Actinastrum sp.	P	A	A
Ankistrodesmus falcatus	A	P	A
A. spiralis	A	P	A
Ankistrodesmus sp.	P	P	P
Aphanochaete repens	A	P	A
Binuclearia sp.	P	A	A
Bulbochaete sp.	P	P	A
Chaetophora sp.	P	P	A
Chara sp.	A	P	A
Chlamydomonas ehrenbergii	A	P	A
C. mirabilis	A	P	A
Chlamydomonas sp.	P	P	A
Chlorella subsalsa	A	P	A
C. vulgaris	A	P	A
Chlorella sp.	P	P	P
Chlorococcum sp.	A	P	P
Chlorotylium sp.	P	A	A
Chodatella sp.	A	P	A
Cladophora glomerata	A	P	A
Cladophora sp.	P	P	P
Closteriopsis sp.	P	P	A
Closterium acerosum	A	P	A
C. acutum	A	P	A
C. calosporum	A	P	A
C. diploporum	A	P	A
C. ehrenbergii	A	P	A
C. incurvum	A	P	A
C. maximum	A	P	A
C. nematodes	A	P	A
C. parvulum	A	P	A

A = Absent ; P = Present

(Contd.)

TABLE 10.1 – *Contd.*

1	2	3	4
C. rostratum	A	P	A
C. tumidum	A	P	A
Closterium sp.	P	P	P
Coelastrum cambricum	A	P	A
C. microporum	A	P	A
C. reticulatum	A	P	A
C. sphaericum	A	P	A
Coelastrum sp.	P	P	A
Coleochaete sp.	A	P	A
Cosmarium auriculatum	A	P	A
C. blyttii	A	P	A
C. dentatum	A	P	A
C. gostyniense	A	P	A
C. hammeri	A	P	A
C. isthmochondrum	A	P	A
C. portianum	A	P	A
C. pseudobroomei	A	P	A
C. pseudopyramidatum	A	P	A
C. retusiforme	A	P	A
C. sublateriundatum	A	P	A
C. tenue	A	P	A
C. trachydermum	A	P	A
Cosmarium sp.	P	P	P
Crucigenia crucifera	A	P	A
C. tetrapedia	A	P	A
Crucigenia sp.	P	P	A
Cylindrocapsa sp.	A	P	A
Desmidium sp.	P	A	A
Dichotomosiphon sp.	P	A	A
Dictyosphaerium pulchellum	A	P	A
Dimorphococcus fritschii	A	P	A
D. lunatus	A	P	A
Draparnaldia sp.	A	P	A
Draparnaldiopsis sp.	A	P	A
Enteromorpha sp.	A	P	A
Eremosphaera sp.	P	A	A
Eudorina sp.	P	P	P
Gloeotaenium loitlesbergeri anum	A	P	A
Golenkinia radiata	P	P	A
Gonium sp.	A	P	A
Hormidium sp.	P	P	A
Hydrodictyon reticulatum	A	P	P
Hydrodictyon sp.	P	A	A

A = Absent ; P = Present

(*Contd.*)

TABLE 10.1 – *Contd.*

1	2	3	4
Kirchneriella contorta	A	P	A
K. obesa	A	A	P
Kirchneriella sp.	P	A	P
Microspora sp.	P	A	P
Mougeotia sp.	P	P	A
Netrium sp.	A	A	P
Nitella sp.	A	P	A
Oedogonium crassum	A	P	A
O. magnusii	A	P	A
Oedogonium sp.	P	P	P
Ostreobium sp.	A	P	A
Pandorina morum	A	P	A
Pandorina sp.	A	P	A
Pediastrum boryanum	A	P	A
P. duplex	A	P	P
P. ovatum	P	P	A
P. simplex	A	P	P
P. tetras var. *excisum*	A	P	A
P. tetras var. *tetraodon*	A	P	A
Pediastrum sp.	P	P	A
Pithophora sp.	A	P	A
Planktosphaeria sp.	A	A	P
Pleurodiscus sp.	P	A	A
Pleurotaenium cylindricum	A	P	A
Radiofilum sp.	P	P	A
Rhizoclonium sp.	A	P	P
Scenedesmus abundans	A	P	A
S. acuminatus	A	P	A
S. arcuatus	A	P	A
S. armatus	A	P	A
S. bicaudatus	A	P	A
S. bijugatus	A	P	A
S. dimorphus	A	P	A
S. falcatus	A	P	A
S. obliquus	A	P	A
S. quadricauda	A	P	A
Scenedesmus sp.	P	P	P
Schizomeris leibleinii	A	P	A
Schizomeris sp.	P	P	A
Schroederia planctonica	A	P	A
Selenastrum gracile	A	P	A
Selenastrum sp.	P	P	A
Sirogonium sp.	P	A	A

A = Absent ; P = Present *(Contd.)*

TABLE 10.1 – *Contd.*

1	2	3	4
Sphaerocystis sp.	P	A	A
Sphaeroplea sp.	P	A	A
Sphaerozosma sp.	A	P	A
Spirogyra affinis	A	P	A
S. borgeana	A	P	A
S. gibberosa	A	P	A
S. hyalina	A	P	A
S. inflata	A	P	A
S. maravillosa	A	P	A
S. paludosa	A	P	A
S. rhizopus	A	P	A
S. setiformis	A	P	A
S. singularis	A	P	A
S. subsalsa	A	P	A
Spirogyra sp.	P	P	P
Staurastrum sp.	A	P	A
Stigeoclonium tenue	A	P	A
Stigeoclonium sp.	P	P	P
Tetraedron minimum	A	P	A
Tetraedron sp. 1	P	A	A
Tetraspora sp. 2	P	P	P
Tetrastrum sp. 3	P	A	A
Treubaria triappendiculata	A	P	A
Ulothrix zonata	A	P	A
Ulothrix sp.	P	P	P
Vaucheria sp.	P	A	A
Volvox sp.	A	P	P
Zygnema sp.	P	P	P
BACILLARIOPHYCEAE			
Achnanthes clevei	A	P	A
A. exigua	A	A	P
A. microcephala	A	P	P
Achnanthes sp.	P	P	P
Amphipleura sp.	P	A	P
Amphora ovalis	A	P	A
A. veneta	A	P	A
Amphora sp.	P	P	P
Anomoeoneis sp.	A	A	P
Asterionella japonica	A	P	A
Asterionella sp.	P	A	P
Bacillaria sp.	P	A	A
Caloneis sp.	P	P	A

A = Absent ; P = Present

(*Contd.*)

TABLE 10.1 – *Contd.*

1	2	3	4
Ceratoneis sp.	P	A	A
Chaetoceros sp.	A	P	P
Cocconeis placentula	A	P	A
Cocconeis sp.	P	P	P
Coscinodiscus commutatus	A	A	P
C. granii	A	A	P
C. radiatus	A	A	P
Coscinodiscus sp.	A	A	P
Cyclotella sp.	P	P	P
Cymatopleura sp.	P	P	A
Cymbella microcephala	A	P	A
C. tumida	A	P	A
C. turgida	A	P	A
C. turgidula	A	P	A
C. ventricosa	A	P	A
Cymbella sp.	P	P	P
Denticula sp.	P	A	A
Diatoma elongatus	A	P	A
D. vulgare	A	P	A
Diatoma sp.	P	A	A
Diatomella sp.	P	A	A
Diploneis sp.	P	A	A
Epithemia sp.	P	A	A
Eunotia sp.	P	A	A
Fragilaria sp.	P	P	P
Frustulia sp.	P	A	P
Gomphoneis sp.	P	A	A
Gomphonema clevei	A	P	A
G. constrictum	A	P	A
G. intricatum	A	P	A
G. lanceolata	A	P	A
G. parvulum	A	P	A
G. sphaerophorum	A	P	A
G. subclavatum	A	P	P
Gomphonema sp.	P	A	A
Grammatophora sp.	A	P	A
Gyrosigma sp.	P	P	P
Hantzschia sp.	P	P	A
Hemidiscus sp.	A	A	P
Leptocylindrus sp.	A	P	A
Mastogloia sp.	A	P	A
Melosira ambigua	A	P	A
M. granulata	A	A	P

A = Absent ; P = Present

(*Contd.*)

TABLE 10.1 - *Contd.*

1	2	3	4
Melosira sp.	P	P	P
Meridion sp.	P	A	A
Navicula cincta	A	P	A
N. cryptocephala	A	P	A
N. cuspidata	A	P	A
N. gracilis	A	P	A
N. gregaria	A	P	A
N. minima	A	P	A
N. mutica	A	P	A
N. salinarum	A	P	A
N. viridula	A	P	A
Navicula sp.	P	P	A
Nitzschia acicularis	A	P	A
N. amphibia	A	P	A
N. communis	A	P	A
N. filiformis	A	P	A
N. gracilis	A	P	A
N. linearis	A	P	A
N. palea	A	P	A
N. parvula	A	P	A
N. rostellata	A	P	A
N. sigmoidea	A	P	A
N. subtilis	A	P	A
N. thermalis	A	P	A
N. tryblionella	A	P	A
Nitzschia sp.	P	P	A
Pinnularia interrupta	A	P	A
P. nobilis	A	P	A
P. viridis	A	P	A
Pinnularia sp.	P	P	P
Pleurosigma angulatum	P	P	A
Pleurosigma sp.	A	P	A
Rhoicosphenia sp.	P	P	A
Rhopalodia sp.	A	A	P
Skeletonema costatum	A	A	P

A = Absent ; P = Present

(*Contd.*)

TABLE 10.1 – *Contd.*

1	2	3	4
Stauroneis sp.	P	A	A
Stephanodiscus sp.	P	A	A
Surirella elegans	A	P	A
Surirella sp.	P	P	A
Synedra acus	A	P	A
S. rumpens	A	P	A
S. ulna	A	P	P
Synedra sp.	P	P	P
Tabellaria flocculosa	A	P	A
Tabellaria sp.	P	P	P
Thallasiosira marginata	A	A	P
XANTHOPHYCEAE			
Centritractus belanophorus	A	P	A
Tribonema bombycinum	A	P	A
Tribonema sp.	P	P	A
CHRYSOPHYCEAE			
Chrysococcus sp.	P	A	A
Dinobryon sertularis	A	P	A
Dinobryon sp.	P	A	A
Synura sp.	P	A	A
DINOPHYCEAE			
Ceratium sp.	P	A	A
Peridinium sp.	P	A	A
EUGLENOPHYCEAE			
Euglena acus	A	P	A
E. oxyuris	A	A	P
E. viridis	A	P	A
Euglena sp.	P	P	P
Heteronema sp.	P	A	A
Phacus caudatus	A	P	P
P. viridis	A	P	A
Phacus sp.	P	P	P
CRYPTOPHYCEAE			
Chroomonas candela	P	A	A
RHODOPHYCEAE			
Batrachospermum sp.	A	P	A
Compsopogon sp.	A	P	A

A = Absent; P = Present

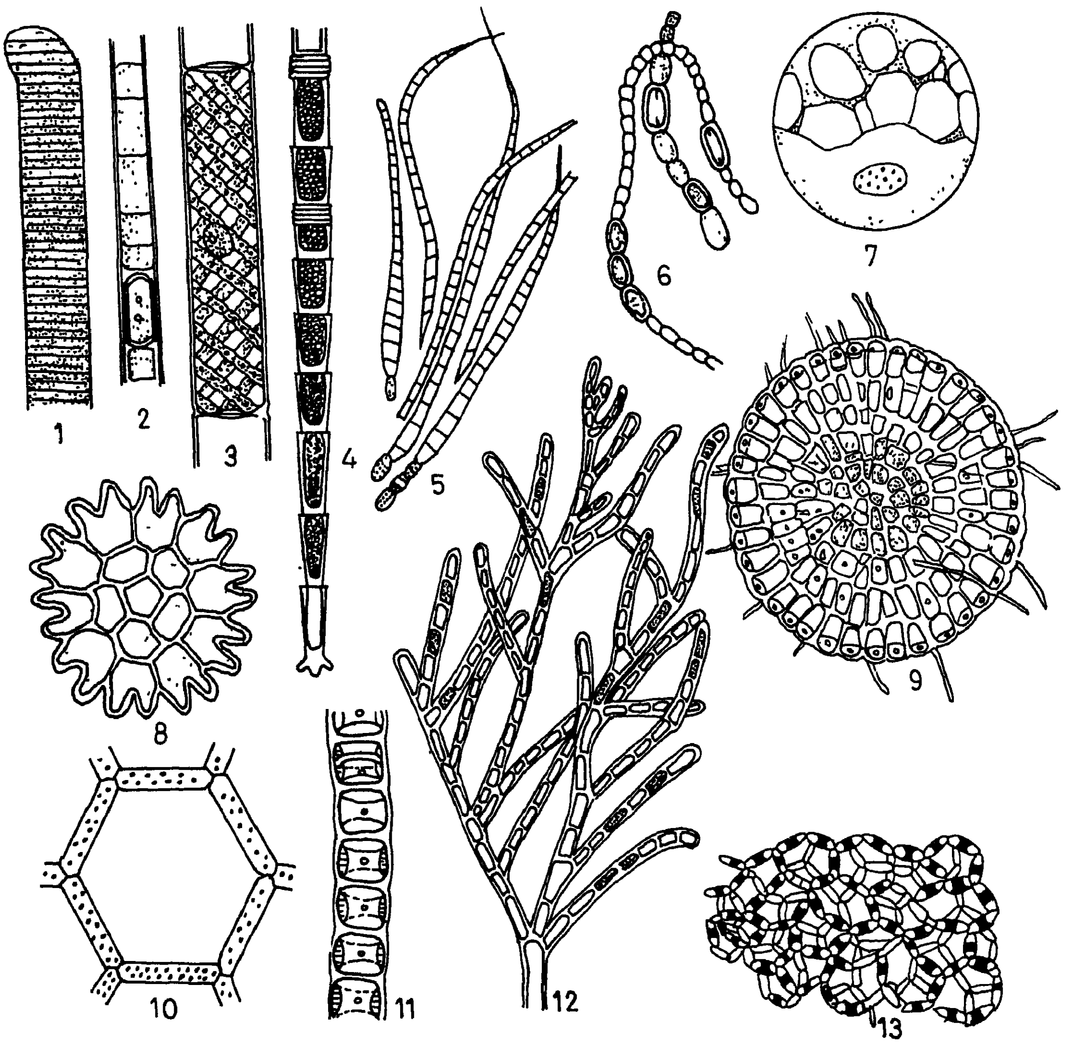

Figure 10.2 : Some Common Algae of the River Ganga

1. *Oscillatona princeps*
2 *Aulosira fertilissima*
3 *Spirogyra subsalsa*
4. *Oedogonium crassum*
5. *Rivularia aquatica*
6. *Nostoc commune*
7. *Chlorella vulgaris*
8. *Pediastrum duplex*
9. *Coleochaete* sp.
10 *Hydrodictyon reticulatum*
11. *Ulothrix zonata*
12. *Cladophora glomerata*
13. *Hydrodictyon reticulatum* (Colony)

Oscillatoria among the filamentous forms were dominant in this stretch of the river. The presence of certain highly pollution-tolerant forms indicates that the Berhampur to Katwa stretch is organically polluted reflecting an overall nutrient-rich situation.

Studies with samples collected near the effluent discharge points of the Rayon Factory, the Jute Mill, Rubber Industries and the Paper Mill between Katwa and Naihati, revealed that the Rayon Factory effluent caused maximum adverse effect (73.37 per cent) on the phytoplankton. Members of the Myxophyceae and Bacillariophyceae were more at these site and *Oscillatoria* and *Diatoma* spp. were the predominant forms.

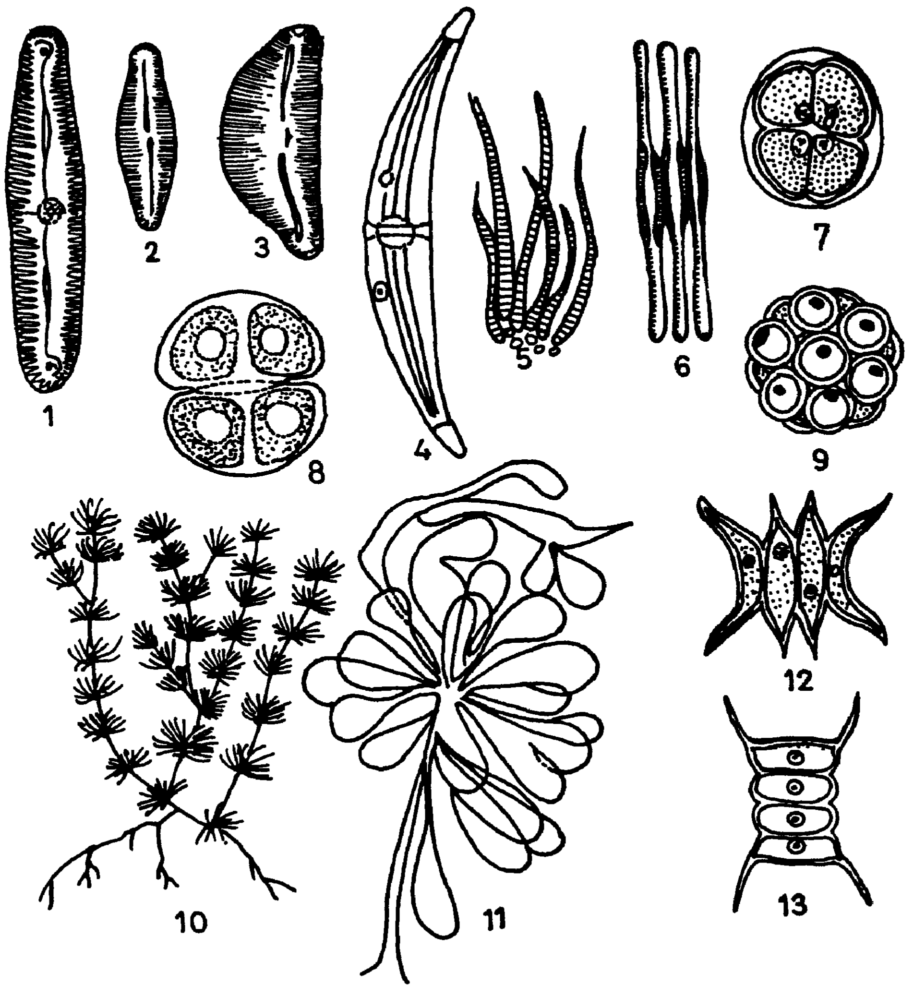

Figure 10.3 : Some Common Algae of the River Ganga

1. *Pinnularia nobilis*
2. *Navicula viridis*
3. *Cymbella* sp.
4. *Closterium acerosum*
5. *Calothrix fusca*
6. *Fragilaria* sp.
7. *Cosmarium tenue*
8. *Cosmarium moniliforme*
9. *Coelastrum microporum*
10. *Chara globosa*
11. *Tetraspora gelatinosa*
12. *Scendesmus dimorphus*
13. *Scendesmus quadricauda*

The monthly variation in phytoplankton density based on studies conducted over two years at Bhagalpur is presented in Figure 10.1. The algae identified in the upper, middle and lower stretches of the river are presented in Table 10.1. The following are the representative algal genera of the river Ganga examined presently : *Anabaena* sp., *Lyngbya magnifica*, *Nostoc* sp., *Oscillatoria* sp., *Phormidium* sp., *Spirulina major*, *Ankistrodesmus* sp., *Chlorella* sp., *Cladophora* sp., *Closterium* sp., *Cosmarium* sp., *Eudorina* sp., *Hormidium* sp., *Hydrodictyon reticulatum*, *Oedogonium* sp., *Pediastrum simplex*, *Scenedesmus* sp., *Spirogyra* sp., *Stigeoclonium* sp., *Tetraspora creassum*, *Ulothrix* sp., *Zygnema* sp., *Achnanthes* sp., *Amphora* sp., *Cocconeis* sp., *Cymbella* sp., *Cyclotella* sp., *Fragilaria* sp., *Gyrosigma* sp., *Melosira* sp., *Pinnularia* sp., *Synedra* sp., *Tabellaria* sp. and *Euglena* sp. Some of these forms are showed in Figures 10.2–10.5 and Plate 3 a & b.

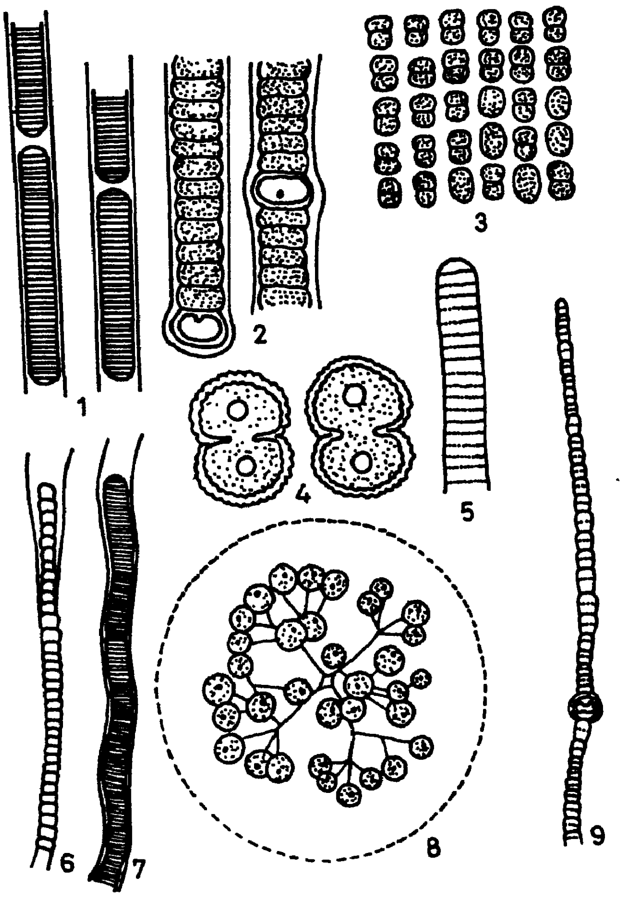

Figure 10.4. : Pollution Sensitive Algae of the River Ganga

1 *Lyngbya magnifica*
2. *Nodularia spumigena*
3 *Merismopedia elegans*
4 *Cosmarium tenue*
5 *Oscillatoria subbrevis*
6 *Lyngbya gracilis*
7 *Lyngbya spirulinoides*
8 *Dictyosphaerium pulchellum*
9 *Anabaena fertilissima*

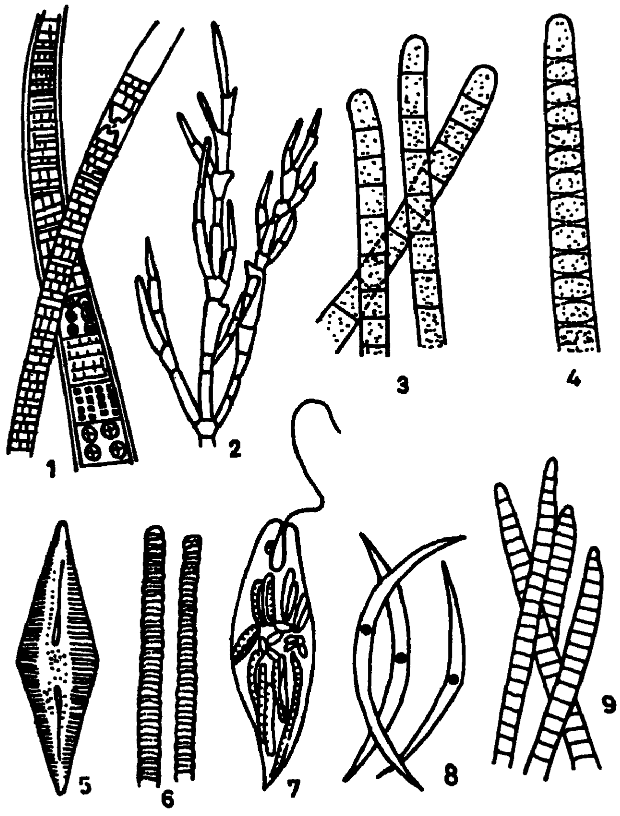

Figure 10.5. : Pollution Tolerant Algae of the River Ganga

1. *Schizomeris leibleinii*
2. *Stigeoclonium tenue*
3. *Oscillatoria chlorina*
4. *Oscillatoria limosa*
5. *Navicula viridula*
6. *Oscillatoria tenuis*
7. *Euglena viridis*
8. *Ankistrodesmus falcatus*
9. *Phormidium uncinatum*

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PLATE 3 (a)

Anabaena circularis – A Pollution Sensitive Alga

PLATE 3 (b)

Euglena acus – Indicator of Organic Pollution

11

Biological Profile of the Ganga : Fungi

K. S. BILGRAMI

In aquatic ecosystems, the presence of extraneous organic and inorganic materials leads to significant changes in the biological components. The association of fungi is common with the plant tissues because of rich cellulose and lignin components. Earlier it was considered that flagellate fungi (lower fungi) play a dominant role as decomposers in the aquatic ecosystem. This does not seem to be true for the riverine ecosystems. It is believed that extra-aquatic non-motile fungi act as the chief decomposers. These fungi come to the system along with decaying twigs and leaves and finally become a part of the sediment.

From Rishikesh to Garhmukteshwar the following fungi were isolated: *Aspergillus* sp., *Aphanomyces* sp., *Curvularia lunata, Fusarium oxysporum, F. lateritium, F. solani, Geotrichum candidum, Leptomitus lacteus, Saprolegnia* sp. and *Schizophyllum commune*. In the stretch between Kalakankar to Phaphamau 16 fungal species were collected. These included *Aspergillus clavatus, A. flavus, A. fumigatus, A. niger, A. sydowii, A. terreus, A. wentii, Alternaria* sp., *Curvularia lunata, Chaetomium funicola, Fusarium* sp., *Phoma* sp., *Saprolegnia* sp., *Achlya* sp., and *Pythium* sp. Of these, species of *Saprolegnia* were isolated from almost all the sites. 38 fungi were recorded from Buxar to Barh : *Rhizopus* sp., *Mucor* sp., *Circinella* sp., *Absidia* sp., *Aspergillus terreus, A. niger, A. nidulans, A. fumigatus, A. flavus, A. versicolor, A. candidus, A. carneus, Trichoderma viride, Paecilomyces* sp., *Spicaria elegans, Papularia sphaerosperma, Alternaria alternata, Fusarium solani, F. moniliforme, Fusarium* sp., *Cladosporium* sp., *Acremonium* sp., *Chaetomium globosum, Curvularia lunata, C. pallescens, Achaetomium luteum, Myrothecium roridum, Rhizoctonia solani, Nigrospora oryzae, Chrysosporium pruinosum, Thielavia terricola, Phialophora* sp., *Sclerotium* sp., *Pithomyces* sp., *Phoma* sp., *Saprolegnia* sp. and *Aphanomyces* sp. A very wide and diverse type of fungi were encountered in water and floating materials between Munger to Farakka which included aquatic and extra-aquatic geofungi. Most of the fungi were found to be associated with floating leaves, twigs and other organic fragments. Majority of these were obtained from the surface of water which reflects their aerobic nature. 102 fungi were isolated out of which 5 were Oomycetes, 24 Zygomycetes, 11 Loculoascomycetes, 5 Coelomycetes, 54 Hyphomycetes and 3 Agonomycetes. Some common fungi of the river Ganga are shown in Figure 11.1.

The density of fungi substantially increased during post flood period. Some of the fungi like *Rhizopus nigricans, Chaetomium globosum, Phoma herbarum, Aspergillus flavus, A. niger, Penicillium islandicum, Trichoderma viride, T. koningii, Drechslera hawaiiensis, D. australiensis, Curvularia lunata, C. pallescens* and *Alternaria alternata* were recorded all the year round. The correlation-coefficient between physico-chemical factors and fungal density showed that fungi prefer moderate to alkaline *p*H. There was significant impact of O_2 level (Table 11.1).

The results indicate that minimum number of fungi was encountered during the summer and maximum in winter (Table 11.2). A large number of fungi may still be obtained from the Ganga system provided a very wide range of "baits" are used to capture them in different eco-regions.

Fungi Identified in the Ganga

OOMYCETES

Achlya debaryana Hump., *A. prolifera* (Nees) de Bary, *Saprolegnia ferax* (Gruith) Thuret, *Pythium carolinianum* Mathews and *P. butleri* Subram.

ZYGOMYCETES

Mucor mecedo (Linn.) Brefeld, *M. racemosus* Fres., *Rhizopus oryzae* Went & Geerling, *R. nigricans* Ehrenb., *R. arrhizus* Fischer, *Absidia corymbifera* Lichth., *A. spinosa* Lendner., *A. reflexa* van Tiegh. & Le Monn., *Actinomucor repens* Schost., *Circinella*

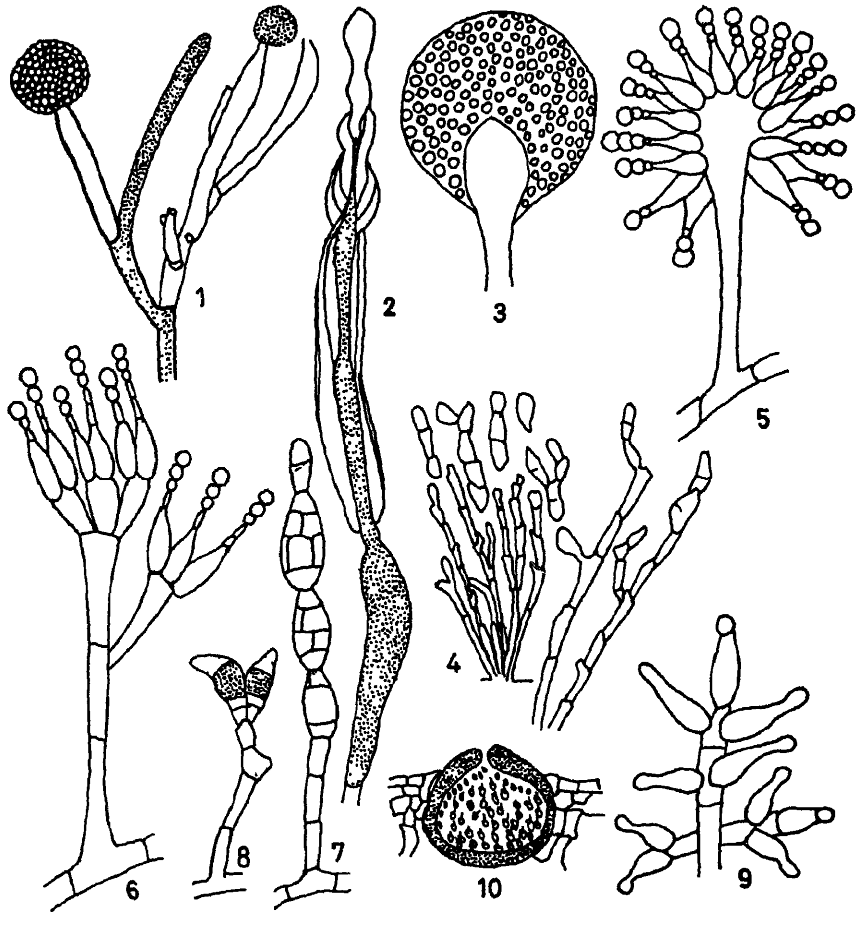

Figure 11.1 : Some Common Fungi of the River Ganga

1. *Achlya* sp.
2. *Saprolegnia* sp
3. *Rhizopus* sp
4. *Cladosporium* sp
5. *Aspergillus* sp
6. *Penicillium* sp.
7. *Alternaria* sp
8. *Curvularia* sp.
9. *Trichoderma* sp.
10. *Phoma* sp.

spinosa van Tiegh. & Le Monn., *C. simplex* van Tiegh., *Choanephora cucurbitarum* (Berk. & Rav.) Thaxt., *Zygorhynchus moelleri* Vuillemin and *Syncephalastrum racemosum* (Cohn) Schroeter.

PYRENOMYCETES

Thielavia terricola (Gill. & Abbott.) Emmons, *Achaetomium luteum* Rai & Tewary, *Chaetomium globosum* Kunze Stend., *C. funicolum* Cooke, *C. indicum* Corda, *C. brasilense* Batista. & Pontual, *C. perulchrum* Ames, *Neocosmospora vasinfecta* Smith, *Podospora nannopodalis* Cain and *Diaporthe arctii* (Laseh) Nites.

LOCULOASCOMYCETES

Botryosphaeria tamaricis (Cooke) Theiss & Syd., *Ophiobolus spirosporous* Ahmad., *O. herpotrichus* (Fr.) Sacc., *Leptosphaeria herpotrichiodes* de Not., *L. aquatica* Tilak & Kulkarni, *L. acuta* (Fries) Karsten, *Thyridium lividum* (Fries) Sacc., *Leptospora rubella* (Pers. ex Fr.) Rabenh., *Thyridium* sp. and *Botryosphaeria obtusa* (Schw.) Shoem.

TABLE 11.1

Correlation Coefficient Between Fungal Density and Physico-chemical Factors

Parameters	Clean Zone		Polluted Zone	
	r	t	r	t
Water temp.	−0.6972	4.5616 $P<0.001$	−0.7712	5.6822 $P<0.001$
*p*H	0.3244	1.6085 $P>0.1$	0.4834	2.5900 $P<0.5$
Turb.	−0.1215	0.5741	−0.3367	1.6771
Cond.	0.2028	0.9714	−0.1633	0.7763
DO	0.5693	3.2479 $P<0.01$	0.6962	4.5489 $P<0.001$
F. CO_2	−0.3970	2.0288 $P>0.05$	−0.3417	1.7053
CO_3	0.0883	0.4157	0.1908	0.9116
HCO_3^- alk.	0.4244	2.1984 $P<0.05$	0.4935	2.6613 $P<0.05$
Total hardness	0.4765	2.5421	0.7011	4.6117 $P<0.001$
Calcium	0.3944	2.0130 $P>0.05$	0.5657	3.2177 $P<0.01$
Magnesium	0.4383	2.0130 $P>0.05$	0.6651	4.1775 $P<0.001$
Sodium	0.4840	2.5942 $P<0.05$	0.4539	2.3892 $P<0.05$
Potassium	0.4482	2.3516 $P<0.05$	0.3094	1.5260
Chloride	0.5634	3.1985 $P<0.01$	0.4705	2.5009 $P<0.05$
Silica	0.8148	6.5921 $P<0.001$	−0.2212	1.0638
Nitrate Nitrogen	-0.0734	0.3456	−0.2743	1.3378
Phosphate Phosphorus	-0.0571	0.2682	−0.2778	1.3563
T.D.S.	-0.2027	0.9709	−0.7559	5.4155 $P<0.001$

Note: Turb = Turbidity Cond. = Conductivity DO = Dissolved Oxygen
F. CO_2 = Free Carbon dioxide CO_3 = Carbonate HCO_3^- alk. = Bicarbonate alkalinity
TDS = Total Dissolved Solids

TABLE 11.2

Seasonal Average Density of Fungi at Clean and Polluted Sites of the River Ganga (x 10^3/litre)

Sites	Seasons		
	Rainy	Winter	Summer
Clean	24.956	29.031	21.900
Polluted	36.368	51.328	35.495

DISCOMYCETES

Ascobolus albidus Crouan.

COELOMYCETES

Massariothea themedae Syd., *Botryodiplodia theobromae* Pat., *Phoma herbarum* Westr., *Phoma nebulosa* (Pers. ex Fr.) Berk. and *Phomopsis vexans* (Sacc. & Syd.) Harter.

HYPHOMYCETES

Aspergillus flavus Link, *A. niger* van Tiegh., *A. terreus* Thom, *A. ustus* (Bain) Thom & Church, *A. sulphureus* (Fres.) Thom & Church, *A. versicolor* (Vuill.) Tiraboschi., *A. fumigatus* Fres., *A. japonicus* Saito, *A. phoenicis* (Corda) Thom., *A. nidulans* (Eidam) Wingate, *A. ochraceus* Wilhelm., *Paecilomyces varioti* Bain., *Penicillium islandicum* Sopp., *P. funiculosum* Thom, *P. citrinum* Thom, *P. pinophilum* Hedgcock., *P. herquei* Bain & Sertory, *P. spiculisporum* Thom, *Gliocladium roseum* (Link) Thom., *Trichoderma viride* Pers. ex Fr., *T. koningii* Oduem., *T. harzianum* Rifai., *Nigrospora sphaerica* (Sacc). Mason, *N. oryzae* (Berk. & Broome) Petch, *Memnoniella echinata* (Riv.) Gall., *Cladosporium cladosporioides* (Fres.) de Vries, *C. oxysporum* (Berh. & Curt.), *C. sphaerospermum* Penz., *C. herbarum* (Pers.) Link, *C. macrocarpum* Preuss., *Fusarium equiseti* (Corda) Sacc., *F. semitectum* Berk. & Rav., *F. moniliforme* Sheldon, *F. moniliforme* var. *subglutinans* Wollenw. & Rein., *F. oxysporum* Shlecht., *Bipolaris tetramera* (McKinney) Shoem., *Drechslera hawaiiensis* Ellis, *D. australiensis* (Bug.) Subram. & Jain, *Curvularia lunata* (Wak.) Boedijn, *Torula herbarum f. quaternella* Sacc., *Alternaria alternata* (Fr.) Keissler, *Curvularia pallescens* Boedijin, *Alternaria gomphrenae* Togashi, *A. dianthicola* Neergard, *Ulocladium chartarum* (Preuss.) Sim., *Epicoccum purpurascens* Ehrenb. ex Schlecht., *Tetraploa aristata* Berm & Br. *Anguillospora longissima* (de Willo). Ing., *A. crassa* Ingold, *Ramichloridium apiculatum* (Mill, Gidd. & Fosa.) de Hoog, *R. schulzeri* (Sacc.) de Hoog, *Stachybotrys atra* Corda, *Botrytis cinerea, Pers.* ex Nocca & Balb. and *Sporothrix* sp. Hektoen and Perkins.

AGONOMYCETES

Sclerotium rolfsii, S. oryzae Catt., *Candida albicans, Aspergillus flavus* Link, *A. niger* Van Tiesh., *A. terreus, A. versicolor* (Vnillemin) Tiraboschi, *Gliocladium roseum, Trichoderma viride, Myrothecium roridum, Stachybotrys atra, Memnoniella echinata, Cladosporium cladosporioides,* (Fresen.) de Vries, *Curvularia pallesceans, Torula herbarum, Alternaria alternata, Epicoccum purpurascens,* (Ehren. ex Schlecht), *Mucor racemosus* and *Zygorhynchus moelleri* were recorded from polluted sites also. Species of *Achyla* and *Saprolegnia* were frequently encountered on decaying organisms and animal/plant tissues. Saprolegniales were also associated with diseases of fishes.

In the Berhampur to Katwa range *Aspergillus* and *Penicillium* were predominant, followed by *Trichoderma, Mucor* and *Curvularia*. Other genera which were frequently encountered included *Alternaria, Cephalosporium, Helminthosporium, Thielavia, Phoma, Chaetomium, Coniothyrium, Oospora, Fusarium* etc.

In the stretch between Katwa to Bandel about 65 fungal species were encountered with predominance of the species of *Aspergillus, Penicillium, Fusarium, Acremonium, Trichoderma, Gliocladium, Phoma* and *Preussia*. Some yeasts like *Trichosporon* and a few sterile Basidiomycetes were also found. The fungal component also included some typical 'white rot' fungi (*Sporotrichum pruinosum* and others).

Fungi were isolated from the various industrial and urban wastes. The species composition of treated or untreated waste waters either of domestic or industrial origin, was predominated by *Aspergillus, Penicillium* and *Fusarium* and to a lesser extent by *Acremonium, Cladosporium Phialophora, Humicola, Preussia* and *Phoma*. Most species were common to all sources while a few were restricted to only a specific source (e.g. *Trichosporon* spp. in paper mill wastes). There were altogether 15 species of *Aspergillus*, 14 species of *Penicillium*, 8 species each of *Fusarium* and *Acremonium*, 5 species each of *Trichoderma* and *Gliocladium* and about 23 of other fungal species obtained from the wastes.

Considering that paper and pulp manufacture wastes are the major constituents of organic waste load of the river between Katwa to Bandel, attempts were made to isolate fungi from paper mill wastes. Observation with respect to selective isolation of lignocellulosic and lignic substrates revealed that some of the species growing on waste are capable of degrading lignin sulfonate and ligno-cellulose substrates (Table 11.3).

Most fungal species were mesophilic and readily adapted to temperature ranges of 32 – 35° C. There are also few species which are adapted for a higher range of 37 – 40° C. These fungal species with two definite optima, one at the meso and the other at the thermophilic range, can be considered as facultative thermophiles. Cellulolytic activity of the waste fungi have also been studied using growth and enzyme activity as parameters. The prominent cellulose decomposers identified are:

1. Strong cellulose decomposers

Phoma leveillei, Trichoderma harzianum, T. viride, Acremonium strictum, Acremonium sp., *Aspergillus fumigatus, Myrothecium roridum, Fusarium merismoides* and *Penicillium funiculosum.*

2. Moderate cellulose decomposers

Preussia dispersa, Phoma capitulum, Aspergillus terreus, Penicillium oxalicum, Gliocladium virens, Acremonium persicinum, Aspergillus sydowii, Fusarium ventricosum, F. solani and *Bipolaris sorokiniana.*

3. Weak cellulose decomposers

Nigrospora oryzae, Trichosporon cutaneum, Penicillium wortmani, P. janthinellum, Aspergillus phoenicis. Most of the strong and moderate cellulose decomposers obtained in the present study are known to have active cellulose hydrolytic enzymes. *Penicillium oxalicum, Fusarium ventricosum,* and *Preussia multispora* have combined ability for cellulose decomposition and xylan utilization.

Ecological adaptation of these aquatic fungi to the environment requires further investigation. Besides mesophilic, there are some facultative thermophiles in the waste. Most species are adapted to lower *p*H range and some showed a preference for inorganic nitrogen sources. *Chaetomium funicola, C. purpulchrum, Myrothecium roridum, Cladosporium cladosporioides* and *Curvularia pallescens* were efficient and quick decomposers of cellulosic materials including the twigs and leaves of the plants.

TABLE 11.3

Selective Isolation of Fungi on Ligno-cellulosic and Lignaceous Substrates from Paper and Pulp Manufacture Waste Water

Selective medium	Fungi isolated
Rice straw meal	*Trichosporon cutaneum, Geotrichum candidum, Phoma capitulum, Aspergillus terreus, A. fumigatus, Preussia dispersa, Trichoderma harzianum, Fusarium* sp.
Mg - lignosulfonate + Basal medium	Anamorph of a Basidiomycetes producing arthospores, *Geotrichum candidum, Preussia* sp., *Phoma capitulum, Aspergillus fumigatus, A. niger, A. terreus, A. nidulans, Sporotrichum pruinosum, Chrysosporium pruinosum,* Unidentified species (2)

Aspergillus niger, A. nidulans, Trichoderma harzianum also occurred on control sets (Sand + basal medium)

12

Biological Profile of the Ganga : Bacteria and Bacteriophages

K. S. BILGRAMI

Bacteria play a major role as decomposers in aquatic ecosystems. Biological quality of water to a very great extent depends upon the qualitative and quantitative pattern of bacteria. The concentration of these organisms varies with the organic load, season, water current, depth, nature of pollutants and physico-chemical quality of the water. A large number of townships and industries are located in the middle and lower stretch of the Ganga. Untreated wastes from the industries and municipalities are discharged directly in the river which result in high concentration of bacteria.

In the upper tract, Gangotri to Rishikesh, maximum bacterial count was recorded in summer (23.449 × 10^6/l) and minimum in winter (1.085 × 10^6/l). Similarly, MPN of total coliform was several times higher in summer (68,675/100 ml) than in winter (12/100 ml). In the stretch between Badrinath to Narora the bacterial count was higher in the rainy season (4.58 × 10^6/ l) followed by winter (4.40 × 10^6/l). In the same stretch maximum coliform was 90/100 ml.

In the middle stretch between Kalakankar to Phaphamau, MPN of total coliform, faecal streptococci and faecal coliform were recorded from all the twelve sites. Maximum total coliform count (9,20,000/100 ml), faecal coliform (16,00,000/100 ml) and faecal streptococci (94,000/100 ml) were recorded during the rainy season and minimum counts of the above bacterial parameters were recorded during winter. Bacteriological characteristics of Ganga water were determined at the major bathing ghats of Varanasi as well as at a point downstream of main sewage discharge. Data reveals that pathogenic bacteria were present in 216 (90.8 per cent) out of 238 samples analysed. 405 isolates were obtained from 216 positive samples (1.9 isolates per positive sample). The most frequently encountered organism was *Pseudomonas* (41.68 per cent samples) followed by typical and atypical *E. coli* (36 per cent) *Enterobacter* (17.86 per cent), *Klebsiella* (10.67 per cent) and *Acenetobacter* 11.29 per cent (Table 12.1). Other pathologically significant isolates included *Shigella* sp., *Salmonella paratyphii* and *Vibrio cholerae*. The results indicate that there is an increased pollution load at the bathing ghats at Varanasi and that the city sewage contributes significantly to bacterial pollution of the Ganga river. [Plate 2 (b)]

Minimum pollution levels were noted in winter which gradually increased to reach the peak by July/August.

From Buxar to Barh the maximum bacterial count recorded was (52.366× 10^6/l) in summer at Patna Medical College Hospital (PMCH) and minimum (0.01694 × 10^6/l) in winter at Barh. Enteric bacteria and *E. coli* were highest at Buxar during the summer followed by the PMCH site at Patna.

The PMCH discharges the waste water and hospital refuse directly into the Ganga. Untreated sewage from the town and unchecked defaecation on the bank of the river is mainly responsible for the high concentration of the coliform and other pathogenic bacterial population at PMCH site (Patna). Observations also revealed that the sediments contained several times higher number of bacteria than overlying water at all the stations round the year. Higher number of bacteria in sediments may be due to more detrital load in the river mud which might be undergoing microbial decomposition.

From Barh to Sultanganj maximum bacterial count was recorded in the rainy season i.e. 1100×10^6/1 while minimum in winter i.e. 360 × 10^6/l. All the polluted samples contain *E. coli*, however, the frequency of pathogenic organisms varies at different places. *Salmonella*, *Shigella*, *Pseudomonas*, *Proteus*, *Klebsiella*, *Micrococcus* and *Streptococcus* sp. were quite frequent in samples of polluted water. *Salmonella* sp. was more frequently isolated than other bacteria.

An estimation of total coliform was made between Munger to Farakka for two successive years (i.e. 1985-87).

TABLE 12.1

Bacterial Profile of the Ganga Water at Varanasi

Bacteria		Total No. of Samples of Water	No. of isolates	Percentage
Vibrio cholerae	0-1	487	7	1.43
Ogawa, classical	-4			
Inaba, classical	- 2			
Ogawa, Eltor	-1			
Non 0-1 *V. cholerae*			17	3.49
Group F. *Vibrio*			3	0.61
Aeromonas hydrophila			2	0.41
Plesiomonas shigelloides			1	0.20
Salmonella typhii			2	0.41
Salmonella paratyphii-A			1	0.20
Salmonella typhimurium			1	0.20
Shigella dysenterial			1	0.20
Shigella boydic			2	0.41
Shigella flexnen			2	0.41
Pseudomonas aeruginosa			203	41.68
Proteus sp.			39	8.00
Providencia sp.			3	0.61
Acenetobacter sp.			55	11.29
Alcaligenes faecalis			58	11.90
Citrobacter sp.			13	2.66
Klebsiella sp.			52	10.67
Enterobacter sp.			87	17.86

There was a sharp fluctuation in their count at different sites. In general the bacterial population was highest in rainy season. At Bhagalpur maximum count (18,000/100 ml) was recorded in rainy season showing a high peak in August. During winter, there was a sharp drop in count followed by an ascending trend from May onwards. Count was invariably higher in the monsoon at all the sites. Maximum count at Bhagalpur was 4,26,800/l in monsoon with the highest peak in July (Figure 12.1). There was a sharp fall in the count during winter with an upward trend, however, from February onwards in 1985-86. During 1986-87, a second peak of lesser magnitude was observed in the month of December.

Faecal streptococci MPN was always higher in the rainy season followed by summer and winter at all the sites from Munger to Farakka. At Bhagalpur it was maximum (7,900/100 ml, 1985-86; 9,400/100 ml, 1986-87) in August and minimum (120/100 ml, 1985-86; 220/100 ml,1986-87) in January.

Altogether, 13 bacterial species were recorded which were identified on the basis of colony characteristics, morphology and bio-chemical tests (Table 12.2). Correlation - coefficients between different physico-chemical parameters and bacterial population revealed that *p*H, dissolved O_2, chloride, hardness, bicarbonate and ionic concentration of water had a negative relationship ($P < 0.05$ to < 0.001), while turbidity and free CO_2 had a significant positive correlation (Table 12.3).

In the Berhampur to Katwa sector coliform population was very low in February. The count, however, began to increase significantly from May onwards. A similar tendency was observed in the case of Vibrios which, increased in April and reached maximum in May. Salmonella-Shigella group of bacteria also showed highest number in May and began to decline thereafter. The range of variation in number per 100 ml was 0-600 in case of coliform, 0-955 in case of vibrios and 0-550 in case of Salmonellae-Shigellae.

TABLE 12.2

Colony Characteristics and Biochemical Tests of Some Bacteria Identified from the Ganga Water

Bacteria	Colony characters	Gram stain	Indole	Methyl red	V.P	Citrate utilization	Oxidase	Catalase	Nitrate reductase	H_2S	Glucose	Lactose	Sucrose
Escherichia coli	On Mac Conkey's agar produces red, non-mucoid colonies with a greenish tinge.	–	+	+	–	–	–	+	+	–	a,g	a,g	a
Aerobacter aerogenes	On Mac Conkey's agar produces paler mucoid colonies. On EMB agar, large light brown colonies	–	–	–	+	+	–	+	+	–	a,g	a,g	a
A. cloacae	Light yellow colonies are produced	–	–	–	+	+	–	+	+	–	a,g	a,g	a
Salmonella sp.	Translucent, grey to opaque on nutrient agar	–	–	–	–	–	–	+	+	+	a,g	–	–
Klebsiella sp.	White, smooth glistening; entire convex on nutrient agar	–	–	–	+	+	–	+	+	–	a,g	a	a
Proteus vulgaris	Grey, opaque, spreading on nutrient agar	–	+	–	–	±	–	+	+	+	a,g	–	a,g
Pseudomonas aeruginosa	Small translucent colonies on EMB agar, colourless at first and creamy white in late stages	–	–	–	–	–	+	+	+	–	a	–	–
Bacillus anthracis	Spreading, dull, opaque in broth culture, turbid and pellicle forming.	+	–	–	+	+	+	–	+	+	a	–	a
Staphylococcus aureus	Yellow, smooth circular, glistening on nutrient agar	+	–	–	–	–	–		+	±	a	a	a
Streptococcus faecalis	Development of acid in azide lactose medium when incubated at 45° C for 48 hrs.	+	–	–	–	–	–	–			a	a	a
Micrococcus sp.	Small, light yellow, dry, raised entire on nutrient agar	+	–	–	–	–	–	±	–	–	a	a	–
Diplococcus sp.	White, transparent, raised, smooth on nutrient agar	+	–	–	–	–	–	–	–	–	a	a	a
Clostridium welchii	Circular, raised opaque moist, entire	+	–					–	+		a,g	a,g	a,g

(a) Acid formation (g) Gas formation

TABLE 12.3

Correlation- coefficient (r) between Physico-chemical and Bacterial Parameters

	Total Coliform	Faecal Streptococci
Water Temp.	0.27330	0.1138
*p*H	– 0.49140*	– 0.4533*
DO	– 0.52580**	– 0.5279**
Free CO_2	0.75660***	0.4531*
Bicarbonate	– 0.37060	– 0.3191
Turbidity	0.63150**	– 0.4799*
T. hardness	– 0.49950*	– 0.3142
Calcium	– 0.43790*	– 0.3208
Magnesium	– 0.50040*	– 0.2831
Sodium	– 0.57050**	– 0.4850*
Potassium	– 0.54820**	– 0.5582**
Chloride	– 0.50560*	– 0.4915*
SiO_2	0.26840	0.3551
NO_3^-N	– 0.10004	– 0.0417
$PO_4^{3-}P$	– 0.44950*	– 0.0363
T.D.S.	– 0.26540	– 0.3849

*** p <0.001; ** p <0.01; * p <0.05

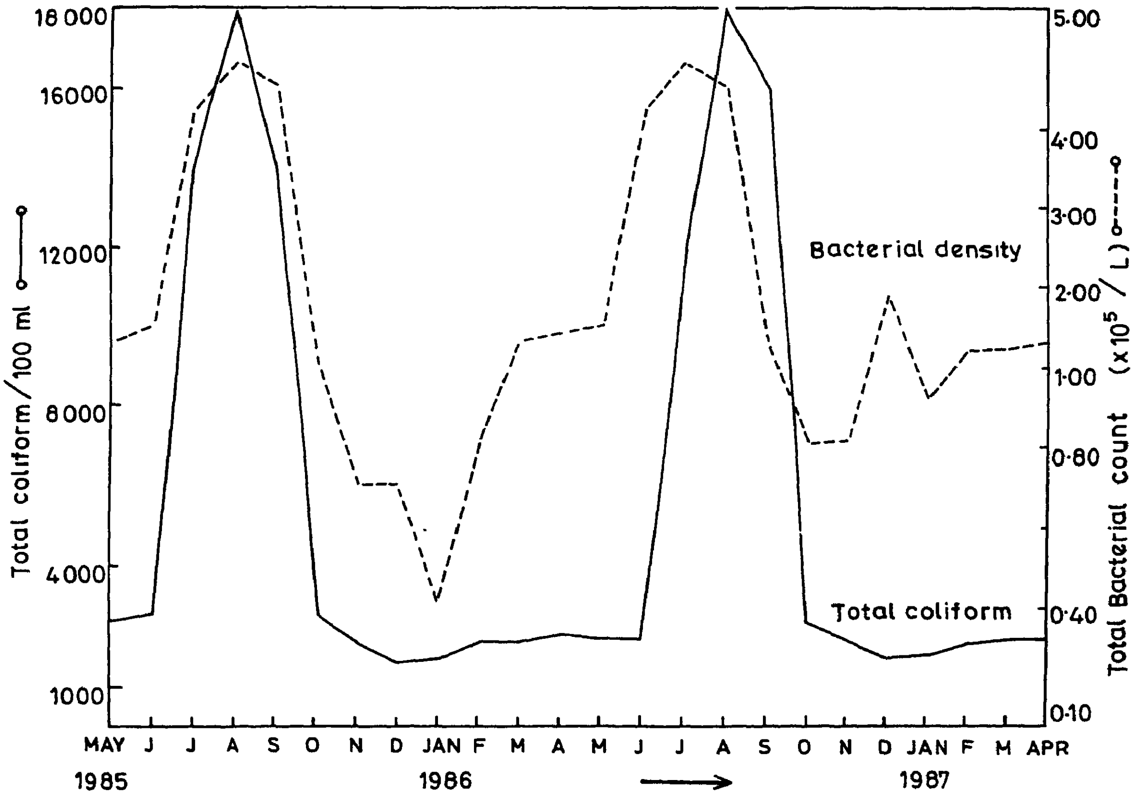

Figure 12.1 : Monthly Variation in Bacterial Population at Bhagalpur (May 1985 to April 1987)

A great majority of the isolates was sensitive to five antibiotics. None of the cultures showed any resistance to Gentamycin and Tetracyclin. Of the total isolates 71.6 per cent were sensitive to all the five antibiotics tested and 28.4 per cent showed resistance to at least one. Incidence of multiple resistance was very low among the isolates (about 3 per cent, Table 12.4). Thus the Ganga river seems to lodge a relatively small number of antibiotic resistant strains.

The presence of a high number of coliforms and other potential human pathogenic bacteria, particularly in rainy season makes the river water unsuitable for drinking purpose. Between Debagram to Naihati and Katwa to Chinsura total bacterial count was maximum in the rainy season ($630 \times 10^6/l$) and minimum in winter ($0.10 \times 10^6/l$) months.

Significant count of heterotrophic bacteria i.e. total coliform, faecal coliform, *Salmonella* and faecal streptococci was made in the lower stretch of the river and the count was much higher than acceptable in river water. The FC/FS ratio indicate faecal contamination of the water. Water containing such high faecal and pathogenic bacteria is, therefore, a potential risk to health. The multiple drug resistance shown by isolates of Enterobacteriaceae is suggestive of a potential for periodic epidemics.

The mean concentration of total coliform organisms in the Ganga water show fairly wide seasonal and sectoral variations. The population of coliforms and enteropathogens increases significantly during the summer and rainy season.

In the plains, practically at all the points the bacterial count was highest during the rainy season. In winter, the count was low. Water temperature and organic load have thus a pronounced influence on bacterial population.

The Ganga water has different types of bacterial viruses (Phages). Study undertaken between Barh and Sultanganj showed that Coliphages were present wherever there was a significant population of the coliform bacteria. The coliform bacteria were comparatively less in the samples taken from the distance of 100 metres from the bank at Sultanganj. Nine types of phages were present in the zone, which seem to cause heavy lysis of the host cells. Though there does not exist any direct relationship between the counts of the host and phages, there is considerable evidence to suggest that the bacterial population was low wherever the phages were high in number.

TABLE 12.4

Resistance of Isolated Bacterial Cultures to Toxic Metals and Five Clinical Antibiotics
Total Number of Cultures Tested =95

Metals and antibiotics	Concentration	Percentage of resistant isolates
Arsenic (ASO_4^{3-})	1 mM	98.9
Cadmium (Cd^{2+})	1 mM	0.0
Copper (Cu^{2+})	1 mM	88.4
Lead (Pb^{2+})	1 mM	97.9
Mercury (Hg^{2+})	0.1 mM	8.4
Nickel (Ni^{2+})	1 mM	90.5
Benzyl penicillin	200 $\mu g/cm^2$ disc	24.2
Chloramphenicol	200 μ g/cm^2 disc	4.2
Gentamycin	20 $\mu g/cm^2$ disc	0.0
Streptomycin	200 μ g/cm^2 disc	5.3
Tetracyclin	200 $\mu g/cm^2$ disc	0.0
No. of isolates sensitive to all the five antibiotics	68	71.6
No of isolates resistant to at least one of the antibiotics	27	28.4
No. of isolates with multiple resistance	3	3.2

Using *Escherichia coli* 594 C-600 strain as host bacteria, evidence for coliphage activity was adduced in water samples from 14 locations between Katwa and Bandel. Two distinct phages were isolated more towards the discharge points than towards the midstream and away from the discharges. There was variation among the sample sites in the incidence of phages.

Detection of specific bacteriophages for *E. coli, Salmonella typhii, Shigella flexneri, Staphylococcus aureus* and *Vibrio cholerae* suggest the presence of these human pathogens at certain sites between Katwa to Naihati in the lower stretch. The bacteriophages can be used for monitoring of biological quality of water.

The significant decrease in the population of *Azospirillum, Azotobacter* and free living *Rhizobium* in soils receiving industrial toxicants by seepage indicates a negative impact on the biological nitrogen fixing potential of soil.

Green fluorescent bacteria occurred in and around the Ganga river, in water bodies, soil near these water bodies and plant surfaces nearby. This has been detected in industrial, town sewerages, agricultural fields and composite drainages. Generally a higher number of such bacteria have been detected in water bodies than in soil or plant surfaces. Most of the isolates were found to be successful soft rotters in different plants. These include potential human and animal pathogens. Presence of these bacteria as epiphytes or saprophytes on plant surfaces, their ability to cause rotting of plant tissues and their survival in soil and water indicate their ubiquitous adaptation. The isolates obtained belong to *Pseudomonas* species.

Samples collected from uninhabited zones invariably had lower coliform counts. Counts for all locations were higher during the rainy season (May to August) than in winter (December to February). Coliform bacterial count gradually diminished with distance along the breadth of the river. Naihati showed an exceptionally high count of faecal coliform during summer. Six coliform species were isolated in varying frequency in the water samples. Extreme faecal contamination of the water under population stress has epidemiological significance.

It was found that 65 per cent of *E. coli,* 75 per cent of faecal streptococci and 99.8 per cent of *Vibrio cholerae* were killed within 24 hours whereas in Sone and Gandak waters they survived for a much longer period. Besides the presence of specific phages the rapid rate of photolysis (oxidation of organic matter under influence of sun light) is also attributed to be a major factor for the bactericidal effect.

A detailed bacteriological study was made at Sultanganj (bathing ghat and downstream) and Bhagalpur (sewage, mixing point and downstream of the river Ganga). The maximum value of total coliform and faecal streptococci was recorded at Sultanganj and Bhagalpur were 3,20,000/100 ml and 9,600/100 ml respectively during rainy season (Table 12.5). Maximum population of indicator bacteria during rainy season is attributed to heavy input of faecal and other organic matter due to intense human activity and bathing by millions of people at that time. At Bhagalpur maximum MPN of total coliform and faecal streptococci at sewage discharge point was recorded during the rainy season, while the lowest density was recorded down the stream during summer and winter respectively. Bacterial contamination was always higher at the sewer mixing zone and this affects the water quality downstream to a distance of about 500 metres. Bacterial concentration in this range was substantially higher than that at the upstream point.

TABLE 12.5

Average Value of Indicator Bacterial Parameters at Sultanganj and Bhagalpur (MPN)

		Sultanganj (/100 ml)		Bhagalpur (/100 ml)		
Season		Bathing ghat	Downstream	Sewage discharge	Mixing point	Downstream
Summer	Coliform	3,500	2,400	7,200	5,120	3,200
	F. streptococci	1,540	1,200	4,260	2, 200	780
Rainy	Coliform	3,20,000	48,000	2,40,000	1,50,000	24,000
	F. streptococci	9,600	4,800	7,200	5,600	4,200
Winter	Coliform	2,800	2,100	6,900	4,200	2,800
	F. streptococci	1,800	940	1,400	2,100	940

13

The Pathogenic Bacteria in the Ganga Water Collected from Twelve Sampling Points in Varanasi

I. C. TIWARI AND P. C. SEN

An attempt was made in this study over the period October, 1985 to March, 1988 to determine the physico-chemical characteristic and bacteriological quality of water samples (487 samples), collected at the nine major bathing ghats, near two sewage outlets and at a point downstream of the main sewage discharge viz. Rajghat Nala. Grab samples were collected at fortnightly intervals between 10 A.M. and 12 Noon in winter and 8-10 A.M. during other seasons, two metres away from the bank and at a depth of 0.5 metre. Samples were examined for *p*H, BOD, COD, dissolved oxygen, nitrate, nitrite, chloride, ammonia and coliform counts according to the standard procedures recommended by the American Public Health Association. For isolation of enteropathogenic bacteria the method as recommended by Read and Joint OIHP/WHO study group on cholera in 1950 was followed. Seventy water samples were specifically screened for *Campylobacter* using Robertson's Cooked Meat medium for enrichment and Bulzler's medium for isolation. Enteric morbidity (Enteric fever, diarrhoea, dysentery, poliomyelitis, hepatitis, etc.) data was also collected simultaneously covering the same period upto March, 1988, from the Infectious Disease Hospital, District Hospital and the Medical Institute Hospital, Varanasi.

The values obtained for *p*H, chloride, ammonia, nitrate, nitrite, dissolved oxygen, biological oxygen demand and chemical oxygen demand indicated high pollution levels at all the sampling points. The physico-chemical parameters as well as the coliform counts showed an increasing trend in the pollution level from the University Ghat to beyond Rajghat Nala. The pollution level at the bathing ghats with M.P.N. as the parameter was highest during autumn followed by rainy season, winter and summer. *Campylobacter* was not isolated from any of the 70 samples that were specifically screened for this organism. The hospitals data showed dmission of many cases with enteric morbidity but no correlation could be obtained between the admission and pollution load.

14

Microbial Population and Bacteriophage Activity in the Ganga Water : An Exploratory Study

M. SEN*

Ganga water is reputed to have marked keeping qualities and can be stored at room temperature for relatively long periods of time as is the common practice in many Hindu homes. This property is surprising because of the obvious and extensive microbiological pollution one notices. Is it possible that the bacteria present in the Ganga are gradually lysed by concurrently occurring bacteriophages? About 40 years ago Pasricha and deMonte of the Calcutta School of Tropical Medicine reported to have adduced evidence for bacteriophage activity and its relation to the epidemics following the bathing festivals such as the Kumbh Mela. (Pasricha and deMonte, 1940). Bacteriophage activity was also detected in a random survey made in this laboratory of 48 samples of the Ganga water collected from Haridwar to Haldia. (Mukherjee, *et al.*, 1984).

The present study was made on water samples taken from the Ganga in the Nadia, 24 Parganas and Hugli Districts of West Bengal. Microbial population was counted by serial dilution technique. For detecting bacteriophages water samples were first centrifuged at 3000 rpm and then filtered through a sintered glass filter (Jena). The filtrates mixed with 1 per cent chloroform were preserved at 4°C. The lytic activity of the filtrates was tested on young and fresh culture of bacteria by following decrease in opacity or appearance of plaques on agar gel plates.

TABLE 14.1

Lytic Activity of Sintered Glass Filtered Water Samples Indicating the Presence of Bacteriophages

Growth expressed as OD at 540 nm.

	Control	Kuntighat	100 m Upstream Kalyani Paper Mills	Rayon Factory	10 m away Majher-char	100 m down stream Indian-Paper Mills	100 m upstr-eam Rayon Factory	Power-House	Mogra Sewage
Sarcina lutea	0.12	0.07*	0.06*	–	–	–	–	–	–
E. coli Row	0.15	–	0.08*	0.69*	0.07*	0.08*	0.09*	–	–
Klebsella pneumoniae	0.21	–	–	–	–	–	–	0.13	–
Staphylacoccus aureus	0.13	–	–	–	–	0.08	–	–	–
Salmonella typhi	0.17	0.08	–	–	–	–	–	–	0.08
E. coli TCI	0.12	–	–	0.08	–	–	–	–	0.05
Shigella flaxneri	0.15	0.09	–	–	–	–	–	–	–

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* Dr (Mrs) M.Sen was assisted by Atanu Bhattacharya in this study.

The plate counts/ml for bacteria, fungi and actinomycetes were in the range of 1,000 – 65,000, 100 – 7000 and 0 – 300 respectively. The lytic activity noted is shown in Table 14.1 indicating the presence of bacteriophages against *E. coli, Vibrio cholerae, Shigella flexneri, Salmonella typhi, Staphylococcus aureus* and *Sarcina lutea.*

It, thus, appears that one way the bacterial population is controlled in the Ganga water may involve the activity of bacteriophages. More detailed work with a large number of bacterial strains isolated from the sewage discharged into the Ganga and the bacterial population of the Ganga will be useful in assessing the importance of bacteriophages in controlling the bacterial pollution of the Ganga.

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15

Biological Profile of the Ganga: Zooplankton, Fish, Birds and other Minor Fauna

K.S. BILGRAMI

In the uppermost zone (Gangotri to Rishikesh), the zooplankton comprised ciliates only and their concentration was 216 u/l and 174 u/l in winter and summer respectively. The group included *Colpoda* and *Paramecium.* The plankton density increased at all such points of discharge of town sewage. From Badrinath to Narora there was a progressive increase in zooplankton concentration and the maximum value was recorded at Satyanarayana (600 u/l approx). Between Rishikesh to Garhmukteshwar, the maximum value was at Bijnor barrage (i.e. 1168 u/l in 1985 and 2414 u/l in 1986) and the minimum value was recorded at Shyampur Khadir (i.e. 140 u/l in 1985 and 190 u/l in 1986). At Haridwar the maximum and minimum values were 340 u/l and 240 u/l respectively in 1985 but was only 38 u/l and 190 u/l respectively in 1986. Altogether 20 forms of zooplankton were identified belonging to Ciliata, Rotifera, Cladocera, Rhizopoda and Copepoda. Some insect larvae were also recorded (Table 15.1). Eight forms thrived in clean habitat while five species preferred polluted waters.

Thirty two forms of zooplankton were identified from Kalakankar to Phaphamau dominated by *Colpedium* sp., *Didinium* sp., *Euglena* sp., *Halteria* sp., *Paramecium* sp., *Stentor* sp., *Vorticella* sp., *Brachionus* sp., *Filinia* sp., and *Keratella* sp. (Table 15.1). Zooplankton population was maximum during summer and minimum during winter at all the sites studied. During July to September the zooplankton concentration was very low at all the sites and ranged between 11 u/l and 297 u/l. The mid-stream samples of the river showed lower numbers probably due to high speed of the water current.

Twenty seven forms of zooplankton were recorded from Buxar to Barh. Rotifers constituted the major segment in this stretch and these were represented by 17 species. Cladocerans and Copepods were represented by five forms each. Concentration of zooplankton varied from 4 - 194, 16 - 72 and 2 - 330 u/l during summer, monsoon and winter respectively in this stretch. At Buxar (upstream) the dominant forms included *Brachionus caudatus, Moina dubia* while near Gandhi Setu (Patna) *Keratella tropica* and *K. cochlearis* were in high concentration. The following pollution indicator species were identified : *Brachionus angularis, B. rubens, B. calyciflorus, B. quadridentata, Keratella cochlearis, Filinia terminalis, F. longiseta, Moina dubia, Daphnia carinata* and *Polyarthra* sp.

From Barh downwards, Rotifers were again the dominant group. Some forms of zooplankton were recorded at Barh of which *K. tropica* and *B. caudatus* constituted the dominant fraction. At Mokameh near the Bata Shoe Factory and McDowell distillery, *Euglena* and *Paramecium* sp. were recorded reflecting high concentration of organic matter.

An extensive survey from Munger to Farakka at six sites gave a total of 40 species of zooplankton of which 4 were protozoans, 21 rotifers, 10 cladocerans and 5 copepods (Table 15.1). The density was highest during summer followed by winter showing a bimodal peak of zooplankton population. During monsoon the population was very low (Figure. 15.1). The zooplankton recorded was 35 - 90 u/l in summer, followed by 12 - 40 u/l in winter and 4 - 30 u/l during the monsoon. *Arcella* sp., *Paramecium* sp., *Brachionus quadridentata* and *Moina brachiata* showed high concentration in polluted waters.

In the stretch of river Ganga between Berhampur to Katwa 4 species of Protozoa, 7 species of Rotifera, 6 species of Cladocera and 4 species of Copepoda were recorded. At Burdwan the predominant pollution tolerant forms were *Arcella* sp., *Paramecium* sp., *Brachionus calyciflorus, B.*

TABLE 15.1
Zooplankton Fauna of the River Ganga

University	Zooplankton
1. Garhwal University (Gangotri to Rishikesh) 0112	Protozoa : *Colpoda, Paramecium*
2. Roorkee University (Badrinath to Rajghat Narora) 0111	Protozoa : *Acanthamoeba, Actinophrys, Amoeba, Colpoda, Euplotes, Lionotus, Loxodes, Paramecium, Oicomonas, Oxytricha, Stylonychia, Vorticella* Rotifer : *Dicranophorus, Platiyas* Crustacea : *Bosmina, Cyclops, Daphnia, Limnocalanus, Macrothrix.*
3. Gurukul Kangri University (Rishikesh to Garhmukteshwar) 0113	Protozoa : *Amoeba, Ceratium Arcella, Difflugia, Vorticella, Colpidium, Epistylis.* Rotifera : *Filinia, Monostyla, Brachionus, Gastropus* Copepoda : *Cyclops* Cladocera : *Daphnia, Moina, Simocephalus.*
4. Feroz Gandhi College, Rae Bareli (Kalakankar to Phaphamau) 0122	*Actinophrys* sp. *Arcela* sp., *Bodos* sp., *Ceratium* sp., *Colpidium* sp., *Didinium*, sp., *Halteria* sp., *Paramecium* sp., *Porodon* sp., *Stylonychia* sp., *Stentor* sp., *Vorticella* sp., *Anuraea* sp., *Brachionus* sp., *B. quadridentata, Cathypna* sp., *Chaenea* sp., *Colurus* sp., *Diaschiza* sp., *Filinia* sp., *Keratella* sp., *Philodina* sp., *Rattulus* sp., *Rotifer neptunia, Chaetonotus* sp., *Dorylaimus stagnalis, Rhabdolaimus* sp., *Cyclops* sp., *Cypris* sp., *Daphnia* sp., Nauplius larvae.
5. Banaras Hindu Univ. (Mirzapur to Ballia) 0123	Not available
6. Patna University (Buxar to Barh) 0124	Rotifera : *Asplanchna* sp., *Filinia terminalis, F. longiseta, Keratella tropica, K. cochlearis, Brachionus caudatus, B. calyciflorus, B. falcatus, B. quadridentata, B. angularis, B. rubens, Testudinella* sp., *Horaella* sp., *Euchlanis dilatata, B. forficula, Hexarthra* sp., *Monostyla* sp., Cladocera : *Bosmina longirostris, Ceriodaphnia* sp., *Simocephalus* sp., *Moina dubia, Daphnia carinata* Copepoda : *Cyclops,* Nauplius larvae, *Neodiaptomus* sp., *Diaptomus* sp.
7. Rajendra Agricultural University, Pusa (Barh to Sultanganj) 0127	Protozoa : *Arcella* sp., *Difflugia* sp., *Vorticella* sp., *Paramecium* sp. Rotifera : *Asplanchna* sp., *Brachionus* sp., *Keratella* sp., *Rotaria* sp. Cladocera : *Moina* sp., *Daphnia* sp., *Bosmina* sp., *Cyclops,* Nauplius larvae.
8. Bhagalpur University (Munger to Farakka) 0126	Protozoa : *Arcella discoides, Centropyxis aculeata, C. ecornis, Difflugia oblonga* Rotifera : *Hexarthra* sp., *Filinia longiseta, F. terminalis, Polyarthra vulgaris, Synchaeta styla, Trichocerca multicrinis, Asplanchna priodonta, Brachionus calyciflorus, B.* angularis, *B. quadridentata, B. diversicornis, Keratella tropica, K. cochlearis, K. serrulata, Monostyla bulla, M. closterocerca, Lecane elasma.*

(*Contd.*)

TABLE 15.1 - *Contd.*

University	Zooplankton
	Cladocera : *Bosmina longirostris, Bosminopsis* sp., *Alona* sp., *A. dentifera, Daphnia bumholtzi, Daphnia carinata, Moina* sp., *Moina brachiata, Diaphanosoma excisum, Ceriodaphnia rigaudi*
	Copepoda : *Neodiaptomus handelii, Mesocyclops leuckarti, M. hyalinus, Cyclops* sp., Nauplius larvae
9. Burdwan University (Berhampur to Katwa)	Protozoa : *Amoeba radiosa, Arcella discoides, Paramecium sp., Difflugia* sp.
	Rotifera : *Brachionus calyciflorus, B. plicatilis, Keratella cochlearis, K. tropica, Filinia longiseta, Rotatoria rotatoria, Platiyas polyacanthus.*
	Cladocera : *Bosmina longirostris, Chydorus sphaericus, Diaphanosoma excisum, Ceriodaphnia* sp., *Moina brachiata, Alonella dentifera.*
	Copepoda : *Neodiaptomus handelii, Diaptomus* sp., *Cyclops leuckarti, Mesocyclops obsoletus.*
10. Kalyani University (Katwa to Naihati)	Protozoa : *Paramaecium* sp., *Euglena* sp., *Colpoda* sp.
	Rotifera : *Asplanchna* sp., *Brachionus rubens, B. falcatus, B. caudatus, B. angularis, B. quadridentata, Keratella vulga, K. cochlearis, K. tropica, Notholca* sp., *Filinia* sp.
	Cladocera : *Moina* sp., *Diaphanosoma* sp.
	Copepoda : *Cyclops* sp, *Diaptomus* sp., Nauplius stage, Cyclops egg.
11. Calcutta University (Bally to Bandel) 0134	Rotifera : *Brachionus angularis, B. diversicornis, B. forficula, B. rubens, B. caudatus, B. calyciflorus, B. falcatus, B. quadridentata, B. plicatilis, Keratella tropica, K. cochlearis, K. vulga, Pompholyx sulcata, Filinia opoliensis, F. longiseta, F. terminalis, Epiphanes* sp., *Lecane luna, Trichocerca cylindrica, Philodina* sp., *Rotaria* sp., *Rotaria neptunia, Hexarthra mira, Polyarthra multiappendiculata, Cephalodella forticula, C. gibba, C. megalocephala, Eosphora anthadis, Asplanchna brightwelli, A. priodonta, A. intermedia, Lepadella padella, Horaella brehmi, Lecane monostyla*
	Cladocera : *Diaphanosoma excisum, Alona rectangulata, A. pulchella, Moina daphnia, Moina mircrura, M. brachiata, Bosmina meridionalis, Pseudosida* sp., *Podon intermedius, Evadne nordmani, Evadne speinifera, Ceriodaphnia* sp.
	Copepoda : *Mesocyclops hyalinus, M. leuckarti, Cyclops himbriatus, S. prascinus, Laophonte bengalensis, Oithona similis, O. rigida, O. brevicornis, Tropodiaptomus orientalis, Pseudodiaptomus aurivilli, P. lobipes, P. annandalei, P. vinghami, P. serricaudatus, Rhinocalanus cornutus, Paracalanus parvus, Acartia spinicauda, A. erythraea, A. centura, A. negligens, Oncea* sp., *Acartiella sewelli, Microsetella rosea, Macrosetella gracilis,* Nauplius, *Heliodiaptomus viddus, Neodiaptomus* sp., *N. schmackeri, N. handelii.*

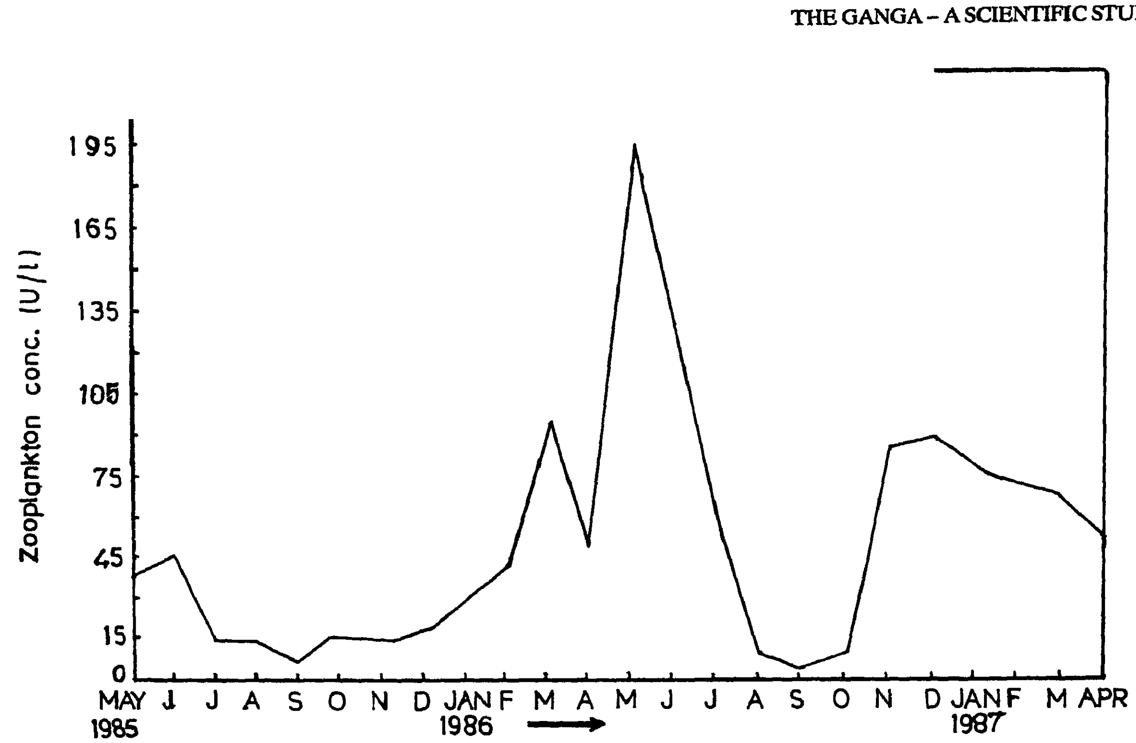

Figure 15.1 : Monthly Variation in Zooplankton Concentration–Bhagalpur (May 1985 to April 1987)

plicatilis, *Keratella cochlearis*, *Rotatoria rotatoria* and *Moina* sp. The concentration of zooplankton was maximum during summer (140 - 160 u/l) followed by winter (58 - 64 u/l) and monsoon (20 - 24 u/l.)

The distribution of zooplankton between Katwa to Naihati was represented by 11 species of Rotifera, a single species of Ostracoda, 4 species of Cladocera and 4 species of Copepoda. Rotifers were abundant in the month of September in Tribeni Jute Mill, Ganges Jute Mill and at Kalyani discharge point near Bandel Thermal Power Plant and Rayon Factory the maximum population of Rotifers were observed during the month of April and November respectively. *Brachionus rubens* was the predominant form in the effluents of Tribeni Jute Mill, Ganges Jute Mill and Kalyani discharge point whereas *B. angularis* was predominant in Rayon Factory and Bandel Thermal Power Plant. Ostracods occurred in large numbers mostly in the month of August but near Rayon Factory and Tribeni Tissue Mill, they occurred in February and November respectively. Cladocerans were numerous in the month of September in the polluted zones of all discharge points except in Ganges Jute Mill where it was found in November. *Moina* sp. and *Bosmina* sp. were the predominant forms in this group. Copepoda were high in number in the month of August at all the discharge points except in Bandel Thermal Power Plant where it occurred during March. The major contributor of Copepoda was *Cyclops* sp. and their nauplii. The peaks of Copepoda were observed during the month of August/September. The number of Rotifera ranged from 706.6 to 2105.4 u/l and 550-809.6 u/l at polluted and control sites respectively. The Copepods ranged from 232 to 2013 u/l and 551.2 to 1649 u/l at polluted and its counter-part respectively. Some common zooplankton of river Ganga are shown in Figure 15.2.

At the point of discharge from the Indian Paper Pulp Factory, where the water temperature was about 38°C and *p*H 8.6, free living protozoans (*Paramecium*, *Euglena* and *Colpoda*) were abundant. But most of these protozoans were killed when this toxic effluent mixed with the main stream of the Ganga water. Similarly, at the point of discharge from the Tribeni Tissue Mill, where water samples contain sulphide, hydroxide, ammonia detergents, there was abundance of free living cliliates (*Colpoda*). Between Bally to Bandel 35 species of rotifers, 12 species of cladocerans, 27 species of copepods were recorded. Among the rotifers, *K. tropica* and *B. angularis* were the dominant species. Copepods were more abundant with naupliis. Cladocerans were dominated by *Bosminopsis* and *Ceriodaphnia* sp. (Table 15.1).

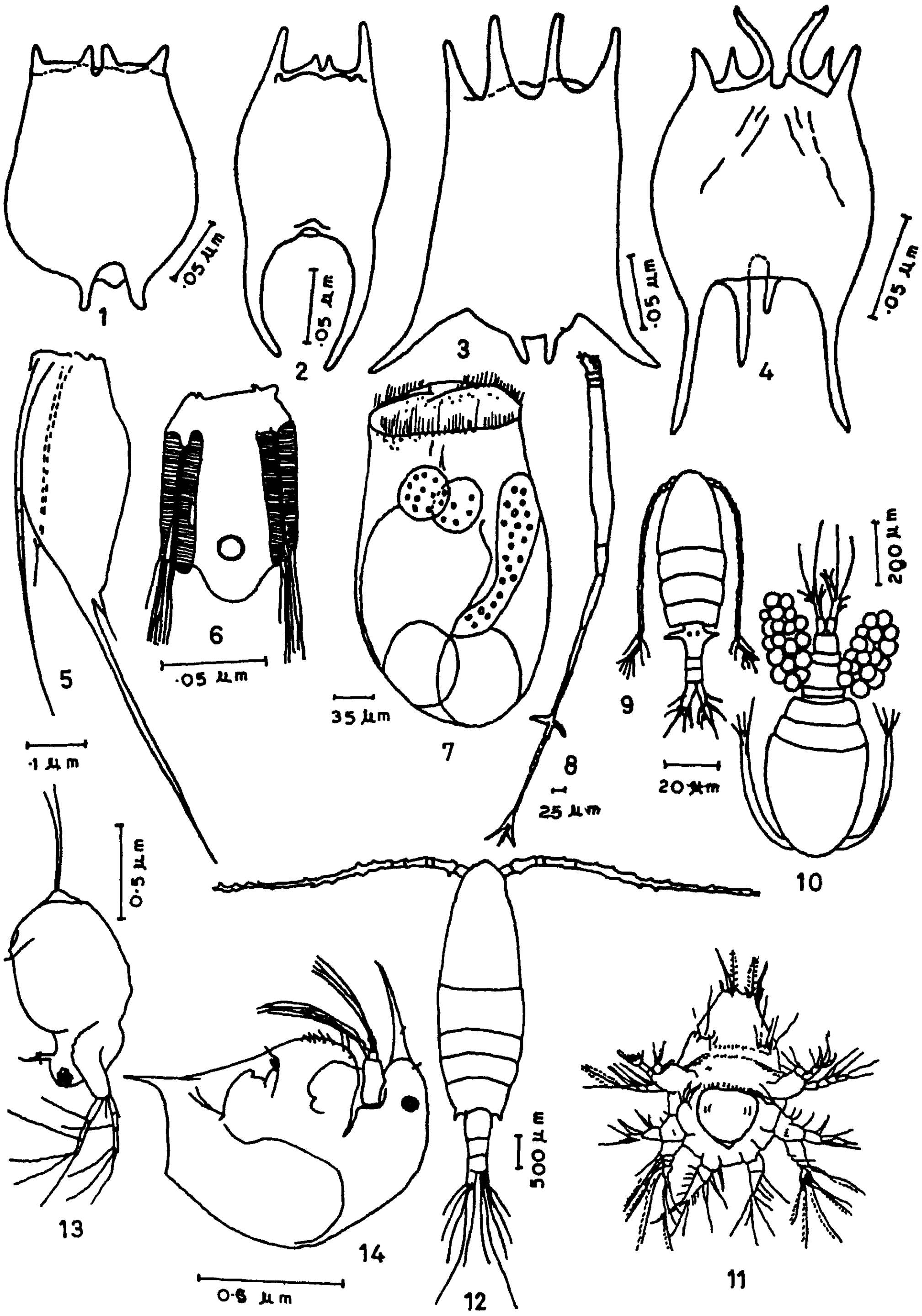

Figure 15.2 : Some Common Zooplankton of the River Ganga

ROTIFERA	1	*Brachionus caudatus*	2.	*B. forficula*
	3	*B. calyciflorus*	4.	*B. quadridentata*
	5	*Filinia opoliensis*	6.	*Polyarthra multiappendiculata*
	7.	*Asplanchna brightwelli*	8.	*Rotaria neptunia*
COPEPODA .	9	*Pseudodiaptomus annandalei*	10.	*Mesocyclops hyalinus*
	11.	*Nauplii of Cyclopoids*	12	*Acartia spinicauda*
CLADOCERA :	13	*Moina micrura*	14	*Bosmina meriodionalis*

FISH

In the upper stretch of river Ganga the most common fishes were *Schizothorax plagiostomus, S. richardsonii, Tor putitora, T. tor, Crossocheilus latius, Garra gotyla, Labeo dyocheilus.* Besides *Xenentodon cancila, Mystus cavasius, Wallago attu,* and *Notopterus* sp. were also encountered. Commercially more important fishes like *Labeo rohita, Cirrhinus mrigala, Catla catla* among the major carps and *Mystus aor, Rita rita, Bagarius* sp., *Pangasius* sp. etc. were not recorded in this zone.

From Kalakankar to Phaphamau *Bagarius bagarius, Mystus aor, Labeo rohita, Catla catla, Cirrhinus mrigala* were found in good numbers. However, the hill stream and cold water fishes that were recorded from the upper stretch of river Ganga were conspicuously absent. *Hilsa ilisha* was also absent in this zone. Altogether 43 species of fishes belonging to 11 different families were found. The family Cyprinidae was at a good concentration at Phaphamau (Table 15.2). Although fish did not show any marked variation in different seasons in general, the varietal diversity was maximum during winter and the post monsoon period.

From Mirzapur to Ballia, the most common fish observed were *Labeo rohita, Catla catla, Cirrhinus mrigala, Bagarius bagarius, Mystus aor, M. seenghala* and *Hilsa ilisha.* Fish spawn was recorded from June to August in this region.

Sixty one species of fishes belonging to 22 different families were recorded between Buxar to Barh. Among the major carps, *Labeo rohita* and *Catla catla* landed in good number at Patna and Buxar and *Cirrhinus mrigala* was poorly represented. Among the catfishes, *Wallago attu* and *Mystus aor* were common. *Bagarius bagarius* and *Hilsa ilisha* were seen very rarely.

Altogether eighty nine species belonging to 22 different families and one species of Elasmobranchii were recorded between Munger and Farakka in the Ganga System and its major tributaries in this region (Table 15.2). Several species are not natives of the Ganga system but they come from the hills and other rivers in monsoon during floods such as *Danio dangila, D. devario, Botia dario* and *B. lohachata.* The fish native to the Ganga have a highly specialized ecological niche. Carps are more in number between Sultanganj and Bhagalpur, at Rajmahal and Maharajpur. *Rita rita, Bagarius bagarius* preferred areas with rocky base. These fish were in good number at Kahalgaon, Pirpainti and Sultanganj. *Rhinomugil orsula* was more frequent in regions with rich putrefying organic matter. *Gudusia chapra, Setipinna phasa* and *Aspidoparia morar* were dominant in Bhagalpur-Khalgaon zone. Juvenile fishing in the post-flood period is very common which results in the destruction of millions of fingerlings of major carps. This practice causes incalculable loss to good quality fishes like *Catla, Rohu* and *Mrigal.* There are several well identified grounds in this region for collection of spawns, fry and fingerlings. Breeding in most of the Ganga fishes is initiated at the onset of monsoon. It would be advantageous to establish some ideal fish seed farms in this region.

Between Berhampur and Katwa, 25 species of fish belonging to 16 different families have been identified. Majority comprise the carnivorous fishes. The commercially important fish species, *Catla catla, Labeo rohita, Cirrhinus mrigala, Labeo calbasu* are getting depleted in this region. The normal food-chain in Ganga ecosystem may get adversely affected if such population imbalance continues. Because of the lesser number of primary consumers (major carps) the secondary consumers (carnivorous fishes) feed upon other aquatic organisms leading to fall in gross fish production. Juvenile fishing of carps is common in this region also.

The Ganga water with waste discharge from the Tribeni Tissue Mill and the Keshoram Rayon Mill was hazardous for the growing carp. Growth was severely affected under the ambient oxygen. Exposed to these polluted water for one month, growth of some vital organs was found to be affected drastically. Associated with this, there was a significant reduction of muscle protein and to some extent of the glucose concentration of the blood. Acid phosphatase activity of the kidney and intestine was also depleted, showing suppression of important metabolic activities. Detergents present in the effluents caused significant fish mortality. In laboratory experiments and partially controlled field investigations with various types of pure detergents revealed that most of the commonly used detergents, were highly toxic to fish and fish seed, reducing growth, causing mortality and hampering reproductive ability.

The main fish fauna available in between Katwa and Naihati were : *Catla catla, Labeo rohita, Puntius puntio, Wallago attu, Mystus vittatus, M. aor, Rita rita, Eutropiichthys vacha, Mastacembelus pancalus, Hilsa ilisha, Boleophthalmus glaucus, Cirrhinus mrigala, Gudusia chapra* and *Xenentodon cancila,* besides *Macrobrachium rosenbergii* and Penaid prawns. Major carps were not available in dry season except during monsoon months when the catch reached 1 – 2 kg per day per spot for a maximum period of 7 days.

TABLE 15.2

Systematic List of Fishes Recorded from the River Ganga
I. Kalakankar to Phaphamau; II: Buxar to Barh; III: Munger to Farakka

Sl. No.	Order	Family	Species	Local Name	I	II	III
CLASS : CHONDRICHTHYES SUB-CLASS : ELASMOBRANCHII							
1.	Squaliformes	Dasyatidae	*Dasyatis sephen* (Forskal)	Sting ray	–	+	+
CLASS · OSTEICHTHYES SUB-CLASS : ACTINOPTERYGII							
2.	Osteoglossiformes	Notopteridae	*Notopterus chitala* (Ham)	Moi, Chital	+	+	+
3.	Osteoglossiformes	Notopteridae	*N. notopterus* (Pallas)	Moi	+	+	+
4.	Clupeiformes	Clupeidae	*Hilsa ilisha* (Ham)	Ilish	–	+	+
5.	Clupeiformes	Clupeidae	*Ilisha motius* (Ham)	Sunri	–	–	+
6.	Clupeiformes	Clupeidae	*Gudusia chapra* (Ham)	Chapri	–	+	+
7.	Clupeiformes	Clupeidae	*G. variegata* (Day)		–	–	+
8.	Clupeiformes	Clupeidae	*Gonialosa manmina* (Ham)	Sohia	–	–	+
9.	Clupeiformes	Clupeidae	*Setipinna phasa* (Ham)	Phasa	–	+	+
10.	Cypriniformes	Cyprinidae	*Chela laubuca* (Ham)	Chelhawa	+	+	+
11.	Cypriniformes	Cyprinidae	*C. atpar* (Ham)		+	+	–
12.	Cypriniformes	Cyprinidae	*Secuncula gora* (Ham)	Darialchalo	+	+	+
13.	Cypriniformes	Cyprinidae	*Salmostoma bacaila* (Ham)	Chelwa	+	+	+
14.	Cypriniformes	Cyprinidae	*Salmostoma untrahi* (Ham)	Chelwa	+	+	+
15.	Cypriniformes	Cyprinidae	*Esomus danricus* (Ham)	Dhawai	–	–	+
16.	Cypriniformes	Cyprinidae	*Danio dangila* (Ham)	Dhawai	–	–	+
17.	Cypriniformes	Cyprinidae	*D. devario* (Ham)		–	–	+
18.	Cypriniformes	Cyprinidae	*D. rerio* (Ham)		–	–	+
19.	Cypriniformes	Cyprinidae	*Aspidoparia morar* (Ham)	Harda	+	–	+
20.	Cypriniformes	Cyprinidae	*A. jaya* (Ham)		+	–	+
21	Cypriniformes	Cyprinidae	*Amblypharyngodon microlepis* (Bleeker)	Dhawai	–	–	+
22	Cypriniformes	Cyprinidae	*Amblypharyngodon mola* (Ham)	Dhawai	+	–	+
23.	Cypriniformes	Cyprinidae	*Barilius bendelisis* (Ham)	Dhawai	–	–	+
24.	Cypriniformes	Cyprinidae	*Barilius bola* (Ham)	Dhawai	–	+	+
25.	Cypriniformes	Cyprinidae	*Puntius chola* (Ham)	Pothia	+	+	+
26.	Cypriniformes	Cyprinidae	*P. chrysopterus* (McCl)	Pothia	+	–	–
27.	Cypriniformes	Cyprinidae	*P. conchonius* (Ham)	Pothia	–	+	+
28.	Cypriniformes	Cyprinidae	*P. sarana* (Ham)	Pothia	–	+	+

+ : Present – : Absent *(Contd.)*

TABLE 15.2 -*Contd.*

Sl. No.	Order	Family	Species	Local Name	I	II	III
29	Cypriniformes	Cyprinidae	*P. sophore* (Ham)	Pothia	+	+	+
30.	Cypriniformes	Cyprinidae	*P. ticto* (Ham)	Pothia	+	+	+
31.	Cypriniformes	Cyprinidae	*Osteobrama cotio* (Ham)	Guda	+	+	+
32.	Cypriniformes	Cyprinidae	*Labeo bata* (Ham)	Bata	+	+	+
33.	Cypriniformes	Cyprinidae	*L. dero* (Ham)		+	–	–
34.	Cypriniformes	Cyprinidae	*L. calbasu* (Ham)	Calbasu	+	+	+
35.	Cypriniformes	Cyprinidae	*L. gonius* (Ham)	Kursa	–	–	+
36.	Cypriniformes	Cyprinidae	*L. rohita* (Ham)	Rohu	+	+	+
37.	Cypriniformes	Cyprinidae	*Tor tor* (Ham)	Mahaseer	–	+	–
38.	Cypriniformes	Cyprinidae	*Cirrhinus mrigala* (Ham)	Mirka	–	+	+
39.	Cypriniformes	Cyprinidae	*C. reba* (Ham)	Reba	–	+	+
40.	Cypriniformes	Cyprinidae	*Crossocheilus latius* (Ham)	Baghwa	–	–	+
41.	Cypriniformes	Cyprinidae	*Catla catla* (Ham)	Catla	+	+	+
42.	Cypriniformes	Cyprinidae	*Garra annandalei* (Hora)	Catla	–	+	+
43.	Cypriniformes	Cyprinidae	*G. gotyla* (Gray)	Catla	–	–	+
44.	Cypriniformes	Cyprinidae	*Noemacheilus botia* (Ham)	Baghwa	–	+	+
45.	Cypriniformes	Cyprinidae	*Botio dario* (Ham)	Baghwa	–	+	+
46.	Cypriniformes	Cyprinidae	*B. dayi* (Hora)	Baghwa	–	–	+
47.	Cypriniformes	Cyprinidae	*B. lohachata* Chaudhuri	Baghwa	–	–	+
48.	Cypriniformes	Cyprinidae	*Lepidocephalichthys guntea* (Ham)	Guhma	–	–	+
49.	Siluriformes	Bagridae	*Mystus aor* (Ham)	Aria	+	+	+
50.	Siluriformes	Bagridae	*M. bleekeri* (Day)		+	+	+
51.	Siluriformes	Bagridae	*M. cavasius* (Ham)	Tengra	+	+	+
52.	Siluriformes	Bagridae	*M. menoda* (Ham)	Belonda	–	–	+
53.	Siluriformes	Bagridae	*M. seenghala* (Sykes)	Aria	+	+	+
54.	Siluriformes	Bagridae	*M. vittatus* (Bloch)	Tengra	+	+	+
55.	Siluriformes	Bagridae	*Rita rita* (Ham)	Ritha	+	+	+
56.	Siluriformes	Siluridae	*Ompok bimaculatus* (Bloch)	Jalkapoor	+	+	+
57.	Siluriformes	Siluridae	*O. pabo* (Ham)	Padba	–	–	+
58	Siluriformes	Siluridae	*Wallago attu* (Schn)	Boari	+	+	+
59.	Siluriformes	Schilbeidae	*Ailia coila* (Ham)	Banspatta	+	+	+
60.	Siluriformes	Schilbeidae	*Clupisoma garua* (Ham)	Garua	+	+	+
61.	Siluriformes	Schilbeidae	*Eutropichthys vacha* (Ham)	Bachwa	+	+	+
62.	Siluriformes	Schilbeidae	*Pseudeutropius atherinoides* (Bloch)	Barusa	+	+	+
63	Siluriformes	Schilbeidae	*Silonia silondia* (Ham)	Sitan	–	–	+
64	Siluriformes	Pangasiidae	*Pangasius pangasius* (Ham)	Pangus	–	+	+

+ : Present – : Absent (*Contd.*)

TABLE 15.2 – *Contd.*

Sl. No.	Order	Family	Species	Local Name	I	II	III
65.	Siluriformes	Sisoridae	*Bagarius bagarius* (Ham)	Bagari	+	+	+
66.	Siluriformes	Sisoridae	*Erethistes hara* (Ham)	Hadda	–	–	+
67.	Siluriformes	Sisoridae	*E. pussilus* (Mull & Tros.)	Teenkata	–	–	+
68.	Siluriformes	Sisoridae	*Hara hara* (Ham)	Panhi	–	+	+
69.	Siluriformes	Sisoridae	*Gagata cenia* (Ham)		–	+	–
70.	Siluriformes	Sisoridae	*Nangra nangra* (Ham)	Panhi	–	–	+
71.	Siluriformes	Sisoridae	*N. punctata* (Ham)	Panhi	+	+	+
72.	Siluriformes	Sisoridae	*Sisor rhabdophorus* (Ham)		+	–	–
73.	Siluriformes	Heteropneustidae	*Heteropneustes fossilis* (Bloch)	Singhi	–	+	+
74.	Siluriformes	Chacidae	*Chaca chaca* (Ham)	Singhi	–	–	+
75.	Atheriniformes	Belonidae	*Xenentodon cancila* (Ham)	Kaua	+	+	+
76.	Perciformes	Centropomidae	*Chanda baculis* (Ham)	Chanda	–	–	+
77.	Perciformes	Centropomidae	*C. nama* (Ham)	Chanda	+	+	+
78.	Perciformes	Centropomidae	*C. ranga* (Ham)	Chani	+	+	+
79.	Perciformes	Sciaenidae	*Sciaena coitor* (Ham)	Bhola	–	+	+
80.	Perciformes	Badidae	*Badis badis* (Ham)	Pathra	–	+	+
81.	Perciformes	Nandidae	*Nandus nandus* (Ham)	Bheda	–	+	+
82.	Perciformes	Mugilidae	*Rhinomugil corsula* (Ham)	Aruari	+	+	+
83.	Perciformes	Mugilidae	*Sicamugil cascasia* (Ham)	Khaksi	–	–	+
84.	Perciformes	Gobiidae	*Glossogobius giuris* (Ham)	Bulla	+	+	+
85.	Perciformes	Anabantidae	*Anabas testudineus* (Bloch)	Kabir	–	+	+
86.	Perciformes	Belontiidae	*Colisa fasciata* (Bloch)	Kabir	–	+	+
87	Perciformes	Channidae	*Channa marulius* (Ham)	Bhohra	–	+	+
88.	Perciformes	Channidae	*C. gachua* (Ham)	Chenga	–	+	+
89	Perciformes	Channidae	*C. punctatus* (Bloch)	Garai	+	+	+
90.	Perciformes	Channidae	*C. striatus* (Bloch)	Soura	+	+	+
91.	Perciformes	Mastacembelidae	*Macrognathus aculeatus* (Bloch)	Bami	–	–	+
92	Perciformes	Mastacembelidae	*Mastacembelus armatus* (Lacep)	Gainhi	+	+	+
93.	Perciformes	Mastacembelidae	*M. pancalus* (Ham)	Patgainchi	+	+	+
94	Perciformes	Hemirhamphidae	*Hyporhamphus limbatus* (Day)	Patgainchi	–	+	+
95.	Tetraodontiformes	Tetraodontidae	*Tetraodon cutcutia* (Ham)	Fokcha	–	+	+
96.	Tetraodontiformes	Tetraodontidae	*T. fluviatilis* (Ham)	Fokcha	–	+	+
97.	Anguiliformes	Anguillidae	*Anguilla bengalensis* (Gray & Hard)	Fokcha	–	–	+

+ : Present – : Absent

TABLE 15.3

List of Aquatic Insects Recorded between Munger and Farakka

Genera / Species	Relative Abundance		
	Abundant	Common	Rare
1	2	3	4
A. ORDER – COLEOPTERA			
Family – Dytiscidae			
Cybister tripunctatus asiaticus Sharp.	–	–	+
Laccophilus chinensis inefficiens Boh.	–	–	+
L. parvulus Aube.	+	–	–
L. anticatus Sharp.	+	–	–
Canthydrus laetabilis Walk.	+	–	–
Canthydrus sp.	+	–	–
Guignotus pradhani Vazirani	–	+	–
Family – Hydrophilidae			
Amphiops sp.	+	–	–
Berosus pulchellus Macleay	–	+	–
B. indicus Mots.	–	+	–
Regimbartia attenuata Fabr.	+	–	–
Hydrophilus olivaceous Fabr.	+	–	–
Laccobius sp.	–	–	+
Family – Gyrinidae			
Orectocheilus gangeticus Wied	+	–	–
Dineutes spinosus Fabr.	–	+	–
Family – Haliplidae			
Haliplus pulchellus Fabr.	+	–	–
B. ORDER – HEMIPTERA			
Family – Corixidae			
± *Corixa hieroglyphica* Duf.	+	–	–
± *C. promontoria* Dist.	+	–	–
Micronecta merope Dist.	+	–	–
Family – Notonectidae			
Antisops sardea Herr Schaff	+	–	–
Family – Pleidae			
Plea frontlis Fieb.	+	–	–
Family – Gerridae			
Gerris fossarum Fabr.	+	–	–
G. spinole Leth. *et* Sevn.	+	–	–
Family – Nepidae			
Ranatra filiformis Fabr.	+	–	–
Laccotrephes griseus Guer.	+	–	–
Family – Belostomatidae			
Diplonychus annulatum Fabr.	+	–	–
C. ORDER – ODONATA			
Family – Gomphidae			
± *Mesogomphus lineatus* Selys	+	–	–
Family – Lebellulidae			
Potomarcha obscura Rambur	+	–	–
Family – Cordulegasteridae			
± *Cordulegaster* sp.	–	+	–
Family – Coenagriidae			
Ischura delicata Hagen.	+	–	–
I. senegalensis Rambur.	+	–	–
D. ORDER – DIPTERA			
Family – Chironomidae			
± *Chironomus* sp.	+	–	–
± *Monopelopia* sp.	+	–	–
Conchapelopis sp.	–	+	–
Clinotanypus sp.	+	–	–
Family – Culicidae			
Anopheles sp.	+	–	–
Culex sp.	+	–	–
E. ORDER – EPHEMEROPTERA			
Family – Baetidae			
± *Baetis* sp. (May Fly)	+	–	–
Cloeon sp.	+	–	–
Ephemerella sp.	+	–	–

± Can be used as indicators of organic pollution.

The fish landing data of *Hilsa ilisha* showed that the river stretch between Kalyani to Tribeni is a good catchment area for *Hilsa*. The amount of *Hilsa* catch between Bansberia to Naihati was low as compared to any other sampling spots. According to fish landing data, the *Hilsa* catch in the river Ganga has been reduced by more than 50% within 15 years. Local people have also started catching juvenile Hilsa which are hardly 3-4 inches in length. Among the different types of prawns caught, the Golda Chingri (*Macrobrachium rosenbergii*) was one of the major catch till a decade back but now this species is dwindling and may disappear form the Ganga.

Other Fauna

The Ganga is a natural repository of a wide range of fauna. Besides fish and zooplankton some other fauna also constitute a link of operative food chain in the system. A large number of species including Nematodes, Annelids, Insects, Molluscs, Amphibians, Reptiles and Mammals were collected from the Ganga.

Nematoda

In the stretch between Munger to Farakka, Phylum Aschelminthes was represented by its lone member, *Helicotylenchus crenacauda*, the nematode worm. They occurred abundantly below the sewage outfall and near the bathing ghats. The nematode *Tylenchorhynchus zeae* was the most dominant species in the sewage fed fields at Berhampur. Other species recorded were *Hirschmanniella oryzae* and *Hoplolaimus indicus* in addition to free living forms. The nematode population of the sewage-fed field was invariably higher than the fields fed with clean water.

Annelida

In the stretch between Kalakankar to Phaphamau three Annelids viz. *Chaetogaster* sp., *Dero* sp. and *Tubifex* sp. were recorded from the river bed. *Namalycastis indica, Nephthys oligobranchia, N. polybranchia, Tubifex* sp. *Branchiura sowerbyi* and *Limnodnlus hoffmeisteri* were the six species of Annelida recorded from Buxar to Barh. Out of these species 4 were also recorded and identified in the stretch between Munger to Farakka. *Nephthys polybranchia* was not seen in this stretch. These forms constitute the major benthic macro-invertebrate fauna of river Ganga in this range.

Insecta

The Class Insecta was represented by *Helocordulia* sp., *Caenis* sp., *Corixa* sp. *Cybister* sp., *Gerris* sp., *Neparobustus, Notonecta* sp., *Perittopus refus, Ranatra elongata, Chironomus* larvae, *Culex* larvae, *Forcipomyia* larvae and *Hydropsyche* sp. in Kalakankar-Phaphamau region.

Aquatic insects were also collected from the river and its tributaries covering areas between Munger to Farakka from the littoral limnetic and benthic zones. Factors like wave action, wind velocity and scarcity of macro-vegetations probably disturb the colonization of aquatic insects. However, the river banks with macro-vegetations and its tributaries provide excellent habitat to aquatic insects. Genera/species of aquatic insects recorded so far are enumerated in Table 15.3.

Influence of various edaphic factors such as moisture content, pH, nitrate, phosphate, organic carbon in controlling the population size, distribution of soil fauna and microbes complex operating in polluted and unpolluted sites was studied in Berhampur-Katwa segment. Among the arthropods collected, the mites were numerically predominant in each case. Of the Acaries, the Oribatiids were specially conspicuous, their population was significantly reduced in polluted sites.

Mollusca

Molluscan fauna were investigated between Rishikesh to Garhmukteshwar, Kalakankar to Phaphamau, Buxar to Barh, Munger to Farakka and Bandel to Bally. Altogether 32 forms of molluscs were identified from river Ganga. Maximum number of species were recorded between Munger to Farakka (15 species) (Table 15.4)

Amphibia

Rana is widely distributed in river Ganga. *R. limnocharis, R. tigrina* and *R. cyanophlyctes* were recorded in the middle and lower stretch of Ganga. Tadpole larvae were quite frequent during the breeding season (Table 15.5)

Reptilia

Trionyx gangeticus, Kachuga kachuga, Lissemys punctata, Gavialis gangeticus (Gharial) and *Natrix piscator* (Grass snake) are some of the important reptiles encountered in the Ganga (Table 15.5).

Birds

Ganga basin is a sanctuary for a large number of birds including the migratory ones. In winter a large number of migratory birds visit the Gangetic belt. Birds recorded in the stretch between Munger to Farakka are listed in Table 15.5.

TABLE 15.4

Molluscan Fauna of the River Ganga

Name of the Univ./College	MOLLUSCS
Gurukul Kangri University 0113	*Lymnaea, Viviparus* *Campeloma, Lamellidens,* *Planorbis*
Feroz Gandhi College, Rae Bareli 0122	*Melania tuberculata* *Lamellidens marginalis* *Viviparous bengalensis* *V. crassa* *Planorbis exustus* *Cyrulus compressus* *Lymnaea amygdalus* *Anodonta* sp., *Helix* sp.
Patna University 0124	*Digoniostoma pulchella* *Melania tuberculata* *M. scabra* *Glessula* sp. *Lymnaea* sp. *Viviparous bengalensis* *Parreysia carrugata* *Corbicula striatella* *C regulans* *Lamellidens marginalis* *L. consobrinus* *Indonia coerulea*

Name of the Univ./College	MOLLUSCS
Bhagalpur University 0126	*Thiara tuberculata* (Muller) *T. scabra* (Muller) *T. lineata* (Gray) *Bellamya bengalensis f. typica* (Lamark) *B. bengalensis f. typica* (Lamark) *Lymnea acuminata* (Lamark) *L. luteola f. ovalis* (Gray) *Cyranuls convexiusculus* (Hutton) *Indoplanorbis exustus* (Deshayas) *Pila globosa* (Swainson) *Parreysia favidens* (Bensen) *P. pachysoma* (Bensen) *Lamellidens marginalis* (Lamark) *Novaculina gangetica* *Corbicula striatella* (Deshayes)
Calcutta University 0134	*Assiminia* sp. *Hydrobia* sp. *Planorbis* sp. *Viviparous* sp. *Amnicola* sp.
Bidhan Chandra Krishi Vishwavidyalaya 0131	*Pila globosa* *Thiara (Melania) lineatus*

Mammals

The class is represented by its lone member, the Gangetic dolphin (*Platanista gangetica*) known as *Susa, Sons or Swis* in different parts. These mammals were recorded between Kalakankar to Phaphamau. Their maximum frequency was noted between Sultanganj to Sahebganj in Bihar. However, indiscriminate killing of this aquatic mammal is threatening its very existence.

TABLE 15.5

Vertebrate Biota of the River Ganga

Sl.No.	Phylum	Class	Order	Family	Types	Common name
1.	Chordata	**Amphibia**	Salientia	Ranidae	*Rana tigrina* (Daudin)	The Indian Bull frog
2.	Chordata	**Amphibia**	Salientia	Ranidae	*R. cynophlyctes* (Schneider)	The water skipperor the skipping frog
3.	Chordata	Amphibia	Salientia	**Ranidae**	*R. limnocharis* (Weigman)	Indian cricket frog
4.	Chordata	Reptilia	Chelonia (Testudinata)	Emydidae	*Kachuga tectum tentona* (Gray)	
5.	Chordata	Reptilia	Chelonia (Testudinata)	Emydidae	*K. kachuga* (Gray)	Kachuga
6.	Chordata	Reptilia	Chelonia (Testudinata)	Trionychidae	*Trionyx gangeticus* (Cuvier)	Mud turtle (Indian softshell Turtle)
7.	Chordata	Reptilia	Crocodilia (Loricata)	Crocodilidae	*Gavialis gangeticus* (Gamelin)	Gharial
8.	Chordata	Reptilia	Squamata	Colubridae	*Natrix piscator* (Linn.)	The checkered water snake
9.	Chordata	Aves	Ciconiformes	Ardeidae (Egrets)	*Egretta alba modesta* (J.E. Gray)	Eastern Large Egret "Bada Bagula"
10.	Chordata	Aves	Ciconiformes	Ardeidae (Herons)	*Ardea cinerea rectirostrin* (Gould)	Eastern Gray Heron "Khyra"
11.	Chordata	Aves	Ciconiformes	Ardeidae (Herons)	*A. purpurea manilensis* (Meyen)	Eastern Purple Heron "Khyra"
12.	Chordata	Aves	Ciconiformes	Ciconidae (Storks)	*Ciconia ciconia ciconia* (Linn.)	White stork "Ujli"
13.	Chordata	Aves	Ciconiformes	Ciconidae (Storks)	*Leptoptilus dubius* (Gamelin)	Adjutant Stork (Denk)
14.	Chordata	Aves	Ciconiformes	Ciconidae (Storks)	*Xenorhynchus asiaticus asiaticus* (Latham)	Black necked Stork (Loha sarang)
15	Chordata	Aves	Ciconiformes	Threskiornit hidae (Ibises)	*Threskiornis melano cephala* (Latham)	White Ibis (Kachator)
16	Chordata	Aves	Ciconiformes	Threskiornit hidae (Ibises)	*Pseudibis papillosa papillosa* (Temminck)	Indian Black Ibis
17.	Chordata	Aves	Ciconiformes	Threskio-rnithidae (Spoonbill)	*Plutalea leucorodia major* (Temminck & Sehlege)	Spoonbill (chamcha)
18.	Chordata	Aves	Anseriformes	Anatidae (Goose)	*Anser anser rubrirostris* (Swinhoe)	Eastern Greyleg Goose (**Kharhans**)

(*Contd.*)

TABLE 15.5 – *Contd.*

Sl.No.	Phylum	Class	Order	Family	Types	Common name
19.	Chordata	Aves	Anseriformes	Anatidae (Goose)	*Anser indicus* (Latham)	Barheaded Goose (Mogli)
20.	Chordata	Aves	Anseriformes	Anatidae (Shelduck)	*Tadoma ferruginea* (Pallas)	Brahminy shelduck (Surkhabh)
21.	Chordata	Aves	Anseriformes	Anatidae (Shelduck)	*Tadoma tadoma* (Linn.)	Common shelduck (Shah Chakwa)
22.	Chordata	Aves	Anseriformes	Anatidae (Shelduck)	*Netta rufina* (Pallas)	Red-crested poachard (Lalsar)
23.	Chordata	Aves	Anseriformes	Anatidae (Dabbling duck)	*Anas clypeata* (Linn.)	Shoveller (Saukhar)
24.	Chordata	Aves	Anseriformes	Anatidae (Dabbling duck)	*Anas strepera strepera* (Linn.)	Gadwell
25.	Chordata	Aves	Charadrii formes	Laridae (Terns)	*Sternaa aurantia*	Indian river tern
26.	Chordata	Aves	Charadrii formes	Laridae (Gull)	*Larus ridibundus* (Linn.)	Black headed gull
27.	Chordata	Aves	Charadrii formes	Laridae (Gull)	*Larus argentalus* (Linn.)	Herring gull
28.	Chordata	Aves	Gruiformes	Gruidae (Crane)	*Grus grus lilfordi* (Sharpe)	Kurch
29.	Chordata	Aves	Gruiformes	Gruidae (Crane)	*Anthropoicea virgo* (Linn.)	Demoiselle crane (Kurra)
30.	Chordata	Aves	Passeriformes	Sturnidae	*Gracula religiosa* (Linn.)	Pahari Myna (Talking Myna)
31.	Chordata	Aves	Peleconi formes	Phalacrocora cidae	*Phalacrocora carbo-sinensis* (Shaw)	Large Cormorant (Jal Kowwa)
32.	Chordata	Mammalia	Cetacea	Platanistidae	*Platanista gangetica* (Lebeck)	Gangetic dolphin (Susa)

16

Possible Food-Chain Operative in the Ganga

K. S. BILGRAMI

Food-chain in any ecosystem involves the transfer of energy from one organism to the other in a systematic manner. The position of organisms in the food-chain is reflected by their trophic level. The producers constitute the base or the first trophic level of the food-chain. Herbivores/phytoplanktivores form the second trophic level while the carnivores which feed upon the herbivores constitute the third trophic level or the level of secondary consumers. In the same sequence we may have the levels of secondary carnivores or even the tertiary carnivores. This depends upon the magnitude of the ecosystem.

Studies conducted at Bhagalpur University based mainly on feeding habits and analysis of the gut-contents show the involvement of the following series of organisms in the food-chain.

A. HERBIVORES *Daphnia carinata* (Cladocera), *Macrobrachium rosenbergii* (Crustacea), Nymphs or *Ephemerella* sp. (Insects), *Pila globosa* (Mollusca), *Rhinomugil corsula* (Fish) and Tadpole larvae (Amphibia).

B. OMNIVORES : *Catla catla* and *Clupisoma garua* (Fishes).

C. CARNIVORES : Nymphs of *Mesogomphus lineatus* (Insects), *Rita rita*, *Glossogobius giuris* & *Wallago attu* (Fishes).

The above-mentioned aquatic organisms were collected from the river Ganga during morning hours (7.00–8.00 A.M) and immediately fixed in 4 per cent formalin. These were quickly transported to the laboratory for gut content analysis. The guts were dissected out and their food contents were examined. The larger pieces were identified by naked eye while smaller ones were studied under binocular microscope. In the case of *Daphnia carinata*, it was not feasible to dissect the alimentary canal, therefore, the organisms were thoroughly washed with distilled water to remove any foreign materials adhering to the body. The alimentary canal was teased out and crushed on the slide with the help of needle and mounted with glycerine under cover slip. Gut contents of some living *Daphnia* were also examined to compare the results.

1. Zooplankton (*Daphnia carinata*) Figure 16.1

The gut content analysis showed this cladoceran to be a herbivore which depends mainly on phytoplankton for its food. Members of Bacillariophyceae (36.5 per cent), Chlorophyceae (48.5 per cent) and Myxophyceae (12.0 per cent) were identified, the rest were put under a separate category referred as other (3.0 per cent). Chlorophyceae were the most preferred food of *Daphnia*.

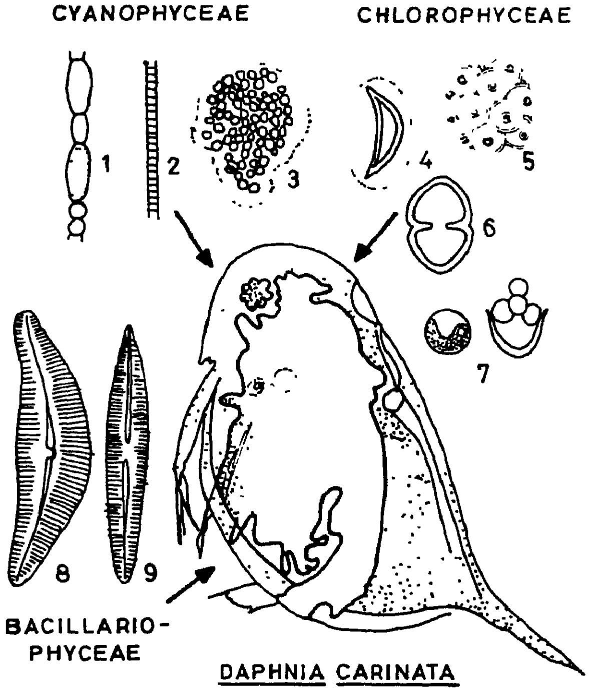

Figure 16.1 : Food Items of *Daphnia carinata*

1. *Anabaena*,
2. *Phormidium*,
3. *Microcystis*,
4. *Closterium*,
5. *Coelastrum*,
6 *Cosmarium*,
7. *Chlorella*,
8. *Cymbella*,
9 *Navicula*.

2. Fresh Water Prawn (*Macrobrachium* sp.) Figure 16.2

Macrobrachium, being herbivorous, mainly feeds on Chlorophyceae and Bacillariophyceae. Besides, some Myxophyceae (*Anabaena* sp.); Zooplankton (*Daphnia* sp.) and macrophytes were also found in the guts of *Macrobrachium*.

3. Gastropod (*Pila globosa*)

Pila globosa is essentially a herbivore. Members of Chlorphyceae alone constitute 54.8 per cent of the total food intake of this gastropod. This is followed by Bacillariophyceae (23.8 per cent), macrophytes (19.0 per cent) and Myxophyceae (2.4 per cent) respectively.

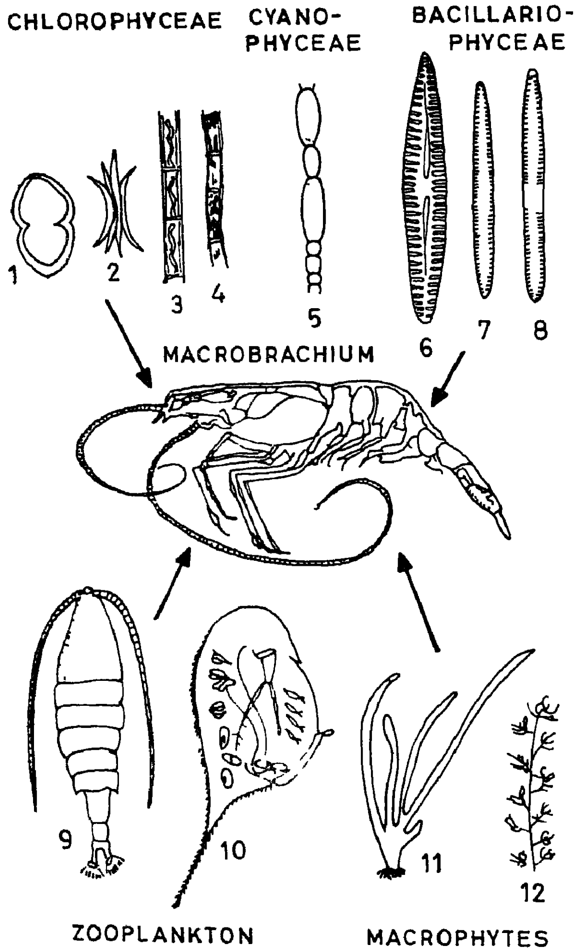

Figure 16.2 : Food Items of *Macrobrachium*

1 *Cosmarium*, 2. *Ankistrodesmus* 3. *Spirogyra*,
4 *Oedogonium* 5 *Anabaena*, 6. *Navicula*,
7 *Synedra*, 8. *Fragilaria* 9 *Diaptomus*
10 *Daphnia*, 11 *Vallisneria* 12 *Ceratophyllum*.

4. Amphibia (*Tadpole larvae*)

The gut content analysis shows that the tadpole larvae of *Bufo* and *Rana* are completely herbivorous. Phytoplankton alone formed 96.5 per cent of the total food items, rest being zooplankton (rotifers and copepods). The plant food comprised Chlorophyceae (47.5 per cent), Myxophyceae (16.9 per cent), Bacillariophyceae (29.6 per cent) and Xanthophyceae (2.1 per cent). Rotifers and copepods were not always present. These constituted 2.5 and 1.0 per cent of the total food respectively. This shows the preference of the tadpole larvae for the Chlorophyceae.

5. Insecta (*Nymphs of Ephemerella* sp.)

Nymphs of *Ephemerella* sp. are primarily herbivorous by habit. Of the recorded dietary components, members of Chlorophyceae, Bacillariophyceae and detritus constituted the major fraction of food of the nymphs. The composition of various food item in the gut were : Chlorophyceae 32.2–61.0 per cent, Bacillariophyceae 25.0–47.0 per cent and detritus 3.5–12.0 per cent Besides, members of Myxophyceae, flagellates were also observed. However, these formed insignificant percentage of food items.

6. Nymphs of *Mesogomphus lineatus*

The gut content analysis of these nymphs confirmed that they were carnivore organisms, feeding on micro-crustacea (Cladocera and Copepoda), rotifers, protozoans, aquatic insects and fish fry. Members of the algal community belonging to Chlorophyceae, Bacillariophyceae and Myxophyceae were also recorded in small percentage during different seasons of the year. However, micro-crustacea, protozoans, rotifera and aquatic insects predominate in the gut.

7. Fish (*Rhinomugil corsula*) Figure 16.3

R. corsula is a surface dweller which moves in shoals. Filamentous algae and diatoms were found to be the main food items of this fish. However, decayed organic matter also contributed significantly. Sand grains and silt are consumed regularly along with decayed organic matter. Diatoms constituted 30.0 per cent, desmids and unicellular algae 10.5 per cent, filamentous algae 20.0 per cent, foliage and roots 29.8 per cent and decayed organic matter 9.7 per cent. Silt and sand grains were not considered as a part of food chain. During the rainy season phytoplankton is not available and the fish thrives mainly on decayed organic matter along with sand grains and silt, aquatic leaves and roots. Such bottom feeding habit is also supported by the presence of an inferior mouth in this species.

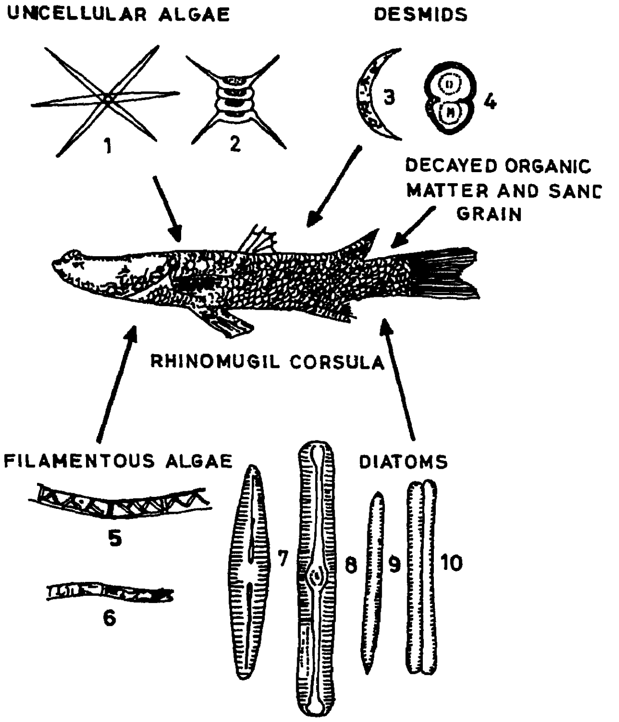

Figure 16.3 : Food Items of Rhinomugil corsula

1 *Ankistrodesmus*
2. *Scendesmus*,
3 *Closterium*,
4 *Cosmarium*,
5. *Spirogyra*,
6. *Oedogonium*
7. *Navicula*,
8. *Pinnularia*
9. *Synedra*
10. *Fragilaria*

8. *Clupisoma garua*

This catfish is essentially an omnivore based on its gut content. It feeds on a variety of food from different strata of the water body. The food contents included 43 3 per cent plant matter consisting mainly the macrophytes and filamentous algae. The animal matter constituted of 4.8 per cent crustaceans, 7.3 per cent insects, 8.5 per cent molluscs and fishes. Detritus and unidentified matter formed 8.6 per cent and 5.0 per cent respectively of the total food. In this fish, surface feeding is mostly during the rainy season and bottom feeding during the winters.

9. *Catla catla* (Figure 16.4)

It is an important and well distributed fish of India. Micro - crustaceans, diatoms and filamentous algae are the main food items of this carp. The percentage composition of different food items determined on the basis of gut contents was : Micro-crustaceans (46.3 per cent), Diatoms (20.8 per cent) Chlorophyceae (15.5 per cent), Macrophytes (9.7 per cent), Rotifers (6.2 per cent) and Protozoans (1.2 per cent).

10. *Rita rita*

The catfish is a carnivore and bottom dweller. The fish shows its preference for molluscs which alone constitute 41.7 per cent of the total food intake. In addition to it, crustaceans (22.73 per cent), fishes (15.7 per cent) and insects (6.9 per cent) were also recorded. Decayed organic matter, mud and sand together formed 13.03 per cent of the total food.

11. *Glossogobius giuris*

This freshwater goby is a carnivore. The gut content analysis shows the predatory nature of this goby and also confirms its cannibalistic habit. Fishes and crustaceans were preferred and constituted 36.1 per cent and 32.3 per cent respectively of the total food. Besides, molluscs and insects contributed 16.2 per cent and 11.8 per cent respectively of the total food. No plant material was detected.

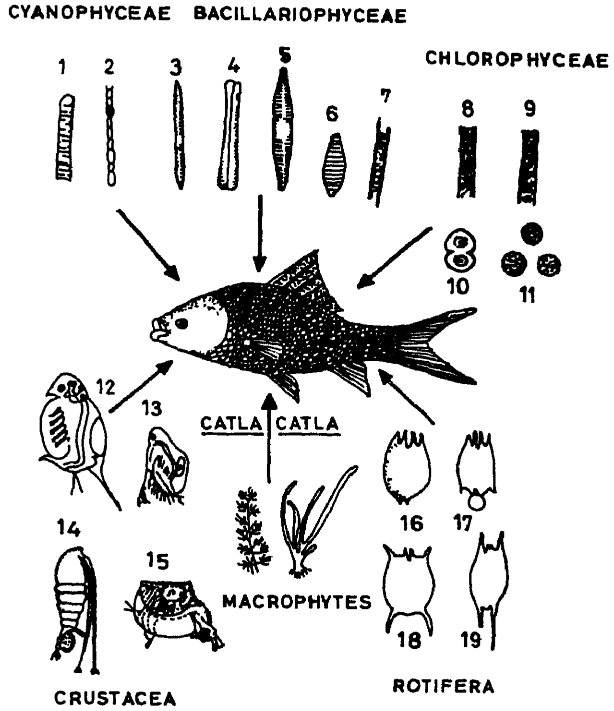

Figure 16.4 : Food Items of Catla catla

1. *Oscillatoria*,
2. *Anabaena*,
3. *Synedra*,
4 *Fragilaria*,
5. *Navicula*,
6. *Diatoma*,
7. *Melosira*,
8. *Spirogyra*,
9. *Oedogonium*,
10. *Cosmarium*,
11. *Chlorococcum*,
12. *Daphnia*,
13 *Diaphanosoma*,
14. *Diaptomus*,
15. *Ceriodaphnia*,
16. *Brachionus*,
17. *Calyciflorus*
18. *B. caudatus* and
19 *B. diversicornis*

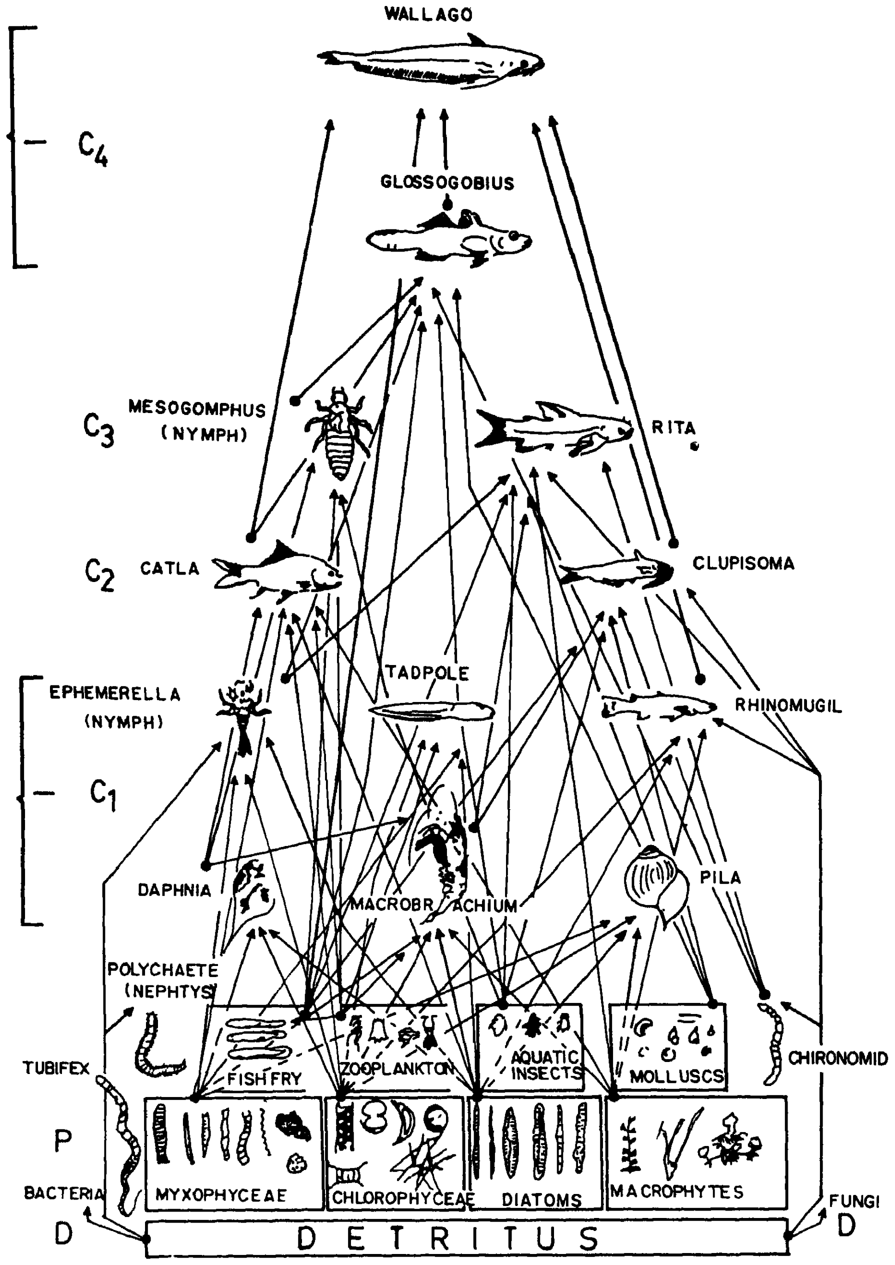

Figure 16.5 : Food-Web in the Ganga River

12. *Wallago attu*

This cat fish is a carnivore. Its gut content analysis confirmed it to be piscivorous. Besides, it also feeds on the dead animal tissue and decayed organic matter.

Food-Chain & Food-Web

On the basis of the food items of different aquatic organisms inhabiting the Ganga ecosystem, a food - chain/food - web model shown in Figure 16. 5 has been prepared:

17

Impact of Flood on Productivity of Diara Land and Vegetation

K.S. BILGRAMI

Diara lands are the characteristic vast land masses of riverine system of the Ganga and its major tributaries in Bihar. These extensive tracts of land masses emerge in the river bed after the recession of flood water. Some of the diaras have got stabilized due to formation of mature soil and vegetation during the time span of hundreds of years. In the state of Bihar approximately 0.6 million hectare of diaras are distributed amongst the Ganga (0.24 million hectare), the Gandak (0.14 million hectare), the Kosi (0.15 million hectare) and the Sone (0.11 million hectare). These lands are highly fertile where fresh silts with rich organic matter gets deposited every year along with the flood waters. Finer sediments are added every year and also the preexisting organic matter of the soil gets easily decomposed during the submergence and it becomes available to newly sprouting plants after emergence of the land. Colonization and succession of macro and micro-flora is greatly affected by the water level. Types of vegetation and productivity of diara land depend on the duration of flood water. On the basis of water level and its duration the diaras are grouped in three categories :

TABLE 17.1

Vegetation of Diara Land

Diara	Natural vegetation	Cultivated crops
Uplands	*Ranunculus scleratus, Cleome viscosa, Achyranthes aspera, Boerhavia diffusa, Desmodium gangeticum, Eclipta prostrata, Sida cordata, Argemone mexicana, Tridax procumbens, Oldenlandia corymbosa, Vernonia cinerea, Heliotropium indicum, Scoparia dulcis, Rungia pectinata, Lippia javanica, Leucas aspera, Altemanthera sessils, Amaranthus* sp., *Digera arvensis, Chenopodium album, Dicanthium annulatum, Cynodon dactylon, Scirpus maritimus, Fimbristylis dichotoma, Cassia tora, Ipomoea aquatica, Rumex dentatus, Croton borplandianum, Chrozophora rotteri, Saccharum spontaneum, Solanum nigrum, Justicia peploides, Euphorbia hirta, E. parviflora.*	*Brassica campestris, Linum usitatissimum, Cicer arietinum, Phaseolus mungo, Pisum sativum, Lathyrus sativus, Triticum vulgare, Zea mays, Hordeum vulgare, Ipomoea batatus, Raphanus sativus, Abelmoschus esculentus, Vigna catjang, Luffa cylindrica, Lycopersicum esculentum.*
Mid High Land	*Phyllanthus simplex, Polygonum glabrum, P. plebegum, Acalypha indica, Lippia javanica, Euphorbia neriifolia, E. hirta, Eclipta prostrata, Argemone mexicana, Cyperus rotundus, Digitaria sanguinalis, Cynodon dactylon, Tamarix dioica, Rumex dentatus, Ranunculus scleratus, Ipomoea aquatica, Cassia tora, Solanum nigrum, Desmodium gangeticum, Oldenlandia corymbosa, Rungia pectinata, Altemanthera sessilis, Diagera muricatra, Fimbristylis dichotoma, Calotropis gigantea, Hibiscus abelmoschus, Rouwolfia serpentina, Calotropis procera, Datura* sp.	*Trichosanthes dioica, Momordica charantia, Lagenaria* spp., *Cucurbita maximum, Citrulus* sp., *Ipomoea batatus, Cucumis melo, Luffa acutangula, L. cylindrica, Cucumis utilissimus.*
Low Land	*Polygonum plebegum, P. glabrum, Euphorbia hirta, Eclipta prostrata, Ranunculus scleratus, Solanum nigrum, Desmodium gangeticum, Boerhavia diffusa, Pedalium murex, Sida cordata, S. obovata, Portulaca quadrifida, Desmodium triflorum, Indigofera linifolia, Lathyrus sativa, Melilotus indica, Vicia sativus, Cynodon dactylon, Dichanthium annulatum, Panicum repens, Setaria verticillata, Hygroryza aristata, Cyperus rotundus, Kyllinga brevifolia, Fimbristylis dichotoma.*	Millets such as Kauni and Cheena (*Panicum* spp.) Rabi cultivation is not done.

Uplands

About 20% of the diaras in Bihar are placed in this category. These areas get flooded either in the second fortnight of August or early September and the water is drained out within a month. Water depth in the flooded upland areas varied from 0.33 to 1.0 metre. The vegetation is of mixed type comprising mostly herbaceous species and grasses (Table 17.1). Cultivation is generally possible all the year round. Oil seeds, pulses, cereals, vegetables and sweet potatoes are cultivated extensively in upland diara.

Mid-high Land

Such diaras occupy about 30% of the area which remain under flood water for more than a month. Water depth varied from 3.0 to 5.0 metres. Vegetation of these mid-high land is mostly herbaceous or some flood resistant shrubs (Table 17.1). Cultivation is possible only for nine months. Cucurbitaceous vegetables such as parwal (*Trichosanthes dioica*), Karela (*Momordica charantia*), Kaddu (*Lagenaria* sp.), Kadmia (*Cucurbita maxima*), Melons (*Citrulus* spp.) and Sweet potato (*Ipomoea batatus*) are cultivated in these areas.

Low Lands

Such lands constitute approximately 50% of the area which remain submerged for more than three months. Water depth varies from 5.0 to 10.0 metres. Grasses, sedges and some herbaceous plants constitute the main vegetation (Table 17.1). Cultivation in low-lands is possible only for about 6 months. Cultivation of millets, Kauni, Cheena (*Panicum* sp.) etc. is done as cash crop. Rabi cultivation is not possible because the land is either submerged or has very high moisture level.

Important crops of diara regions (Uplands, Mid-high lands and Low lands) of Munger, Bhagalpur and Sahibganj districts are given in Table 17.1.

The impact of flood on primary production was studied in Shankarpur diara near Bhagalpur during 1985-87 and a comparison of natural production and production in cultivated lands was done.

Total net primary production (TNPP) in 1985-86 varied from 13.09 gm m^{-2} (May) to 212.05 gm m^{-2} (July) in natural field whereas in cultivated land it was 3.9 gm m^{-2} in May and 1356.64 gm m^{-2} in February (Figure 17.1).

During 1986-87 the TNPP in natural field ranged from 1.48 gm m^{-2} (August) to 209.05 (July) whereas the value in cultivated land ranged from 8.75 gm m^{-2} in May to 11.53 gm m^{-2} in February.

The average value of TNPP in pre-flood period (1985-86) in natural field was 146.6 gm m^{-2} while value in cultivated field was 133.0 gm m^{-2} (Table 17.2). In the year 1986-87 the value in pre-flood period of natural field was 133.3 gm m^{-2} whereas in cultivated field it was 178.3 gm m^{-2}. However, during the flood in both the years the total primary production could not be evaluated because of complete submergence of the lands. Apparently it was negligible. In post-flood period the average TNPP during 1985-86 in natural field was 46.8 gm m^{-2} while in cultivated field the value was about eight fold higher (543.1 gm m^{-2}). In 1986-87 the value was 75.6 gm m^{-2} in natural field and in cultivated field it was 478.1 gm m^{-2} (Table 17.2). More primary productivity in cultivated field was obviously due to input in form of fertilizers, high yielding seeds and water.

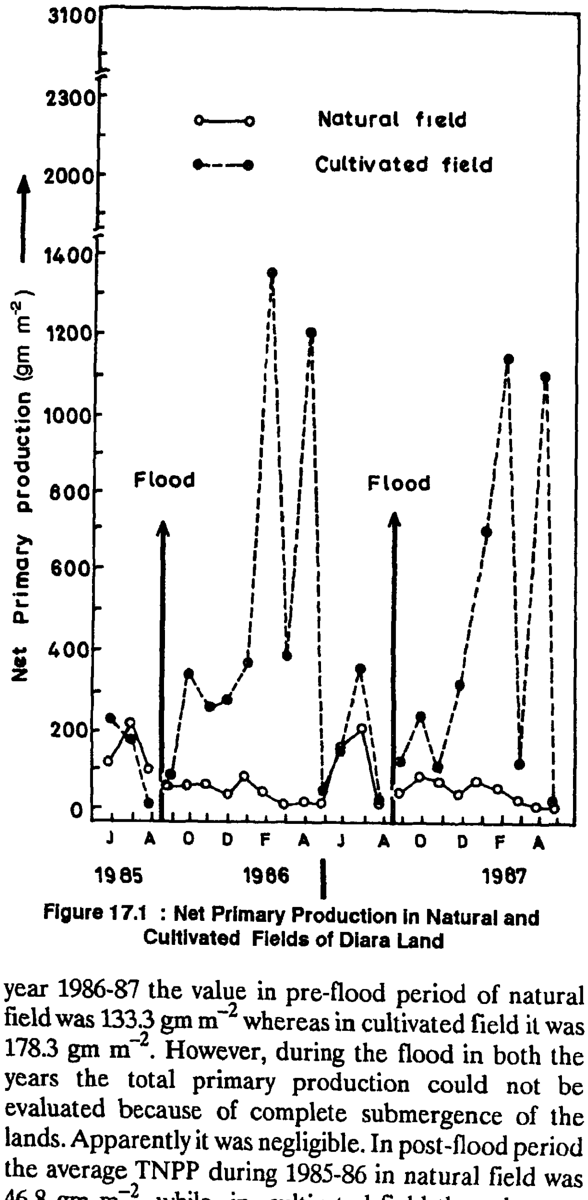

Figure 17.1 : Net Primary Production in Natural and Cultivated Fields of Diara Land

TABLE 17.2

Average Total Net Primary Productivity During Pre Flood & Post Flood

Year	1985-86 gm m^{-2}		1986-87 gm m^{-2}	
Sites	Natural	Cultivated	Natural	Cultivated
Pre-flood	146.6	133.0	133.3	178.3
Post-flood	46.8	543.1	75.6	478.1

18

Biomonitoring of Water Quality of the Ganga

K. S. BILGRAMI

Harmful consequences of pollutants in aquatic ecosystem are often not detected at an early stage. Long term exposure can result in serious damage or death of the sensitive biota. This leads to significant alteration in species composition/diversity in the ecosystem. Species which are more sensitive to pollutants can get diminished or deformed; on the contrary some of them can develop tolerance to the changed environment. Organisms thus act as indicators of a particular habitat and environment. Such organisms are known as bioindicators. For monitoring of water quality use of bioindicators is gradually gaining greater acceptability and popularity.

Some attempts were made to monitor the river with the help of indicator organisms taking the following important parameters into consideration :

(i) Species Diversity Index
(ii) Indicator Bacterial parameters
(iii) Pollution tolerant/sensitive biota

I. Species Diversity Index

Species diversity of living organisms is considered as a scale of measurement of water quality and this is based on the principle that in clean water species diversity is higher than the diversity in polluted water Species diversity is generally expressed as the ratio of the number of species to the number of individuals in a given community or habitat. The species diversity index was calculated according to Shannon and Weaver (1963).

Study of species diversity of phytoplankton was made at six sampling stations from Munger to Farakka but at Sultanganj and Bhagalpur attempts were made to show the impact of human activities and sewage discharge. Species diversity index of phytoplankton was maximum in upstream at both the stations (Sultanganj– 4.7246 to 3.2625; Bhagalpur – 4.6804 to 3.2560). However, this index sharply declined at bathing ghat (Sultanganj - 0.8145) and sewage discharge point (Bhagalpur – 0.7258). Based on the scale (Wilhm and Dorris, 1966), water quality of the main stream (i.e.upstream) in all the six sites from Munger to Farakka comes under clear zone. At Sultanganj (bathing ghat and downstream) the diversity index during rainy season was less than 1.0 which indicates heavy load of organic pollution (Table 18.1). This could be attributed to intense human activities during "Sawan Mela" At Bhagalpur, the value was one to less than one at both sewage discharge and mixing point which is indicative of very poor quality of water.

TABLE 18.1

Average Species Diversity index of Phytoplankton of Different Sites of the River Ganga (Shannon and Weaver)

	Munger	Sultanganj			Bhagalpur				Maharajapur	Rajmahal	Farakka	
	Main Stream	Up Stream	Bathing Ghat	Down Stream	Up Stream	Sewage	Meeting Point	Down Stream	Up Stream	Up Stream	Up Stream	Down Stream
SUMMER	4.8967	4.7246	3.1964	4.1216	4.6804	0.7258	1.1142	2.4264	4.9984	5.6241	5.2404	4.2426
RAINY	3.2421	3.2625	0.8145	0.9168	3.2560	0.7824	0.8256	1.8240	3.5642	3.4248	3.6242	3.0224
WINTER	4.7842	4.6484	3.6569	4.2328	4.4286	0.7591	0.9401	2.2624	4.8426	5.0266	5.1224	4.1618

TABLE 18.2

Diversity Index (H) of Benthic Macroinvertebrates (Shannon and Weaver)

Month	Station						
	I	II	III	IV	V	VI	VII
July,1985	1.069	–	1.431	1.276	0.899	1.272	1.590
August,1985	–	–	0.322	–	1.520	–	–
September,1985	–	–	0.855	0.690	1.099	–	–
October,1985	–	–	–	0.673	–	0.673	–
November,1985	–	–	0.694	–	1.067	–	–
December,1985	–	–	1.480	1.853	2.036	1.846	–
January,1986	1.496	1.557	1.493	–	0.499	1.506	1.322
February,1986	2.262	2.064	1.664	–	0.804	0.934	0.803
March,1986	1.926	1.520	1.581	0.670	1.167	1.729	–
April,1986	2.047	1.889	1.011	–	1.046	1.871	–
May,1986	1.334	1.710	1.072	–	0.526	1.219	–
June,1986	1.752	2.063	1.394	–	0.751	0.961	–
July,1986	0.694	1.494	1.037	–	1.016	1.159	0.960
August,1986	–	1.006	0.950	–	1.301	0.954	–
September,1986	–	–	0.958	–	0.977	–	–
October,1986	1.044	–	1.243	–	–	1.098	–
November,1986	1.891	1.496	0.734	0.640	1.415	1.286	1.044
December,1986	2.082	2.026	1.379	1.388	1.457	1.837	1.554
January,1987	1.859	2.070	1.104	1.524	1.534	1.752	1.336
February,1987	2.075	2.388	1.040	1.364	1.844	1.891	1.658
March,1987	2.281	2.031	0.983	1.759	1.681	2.170	2.219
April,1987	2.026	2.015	0.989	1.546	1.768	0.874	1.811
May,1987	1.975	1.883	1.286	1.173	1.141	2.173	2.088
June,1987	1.513	2.033	1.253	0.936	1.304	2.157	1.791

I = Buxar(U/S), II = Buxar(town), III = PMCH(Patna),
IV = Gandhi Setu (Patna), V = Fatuha, VI = Barh (town),
VII = Barh (D/S.)

Community structure of macrobenthic invertebrate population has frequently been used to evaluate the ecological health at streams. Bottom organisms are particularly suitable for such studies because of their relatively low mobility which enables them to come in contact with various types of newly added materials for a longer span.

Study of species diversity of benthic macro-invertebrates was conducted at seven stations from Buxar to Barh (Table 18.2). Maximum species diversity of benthic macroinvertebrates was recorded at Buxar upstream. It was 2.281 during March 1987. High diversity was obtained during winter and early summer at Buxar. The minimum diversity index (0.322) was obtained near PMCH, Patna. Generally, the species diversity near Patna was lower than that of other stations but usually the diversity was more than one. Based on the criterion laid down by Wilhm and Dorris (1966) the stretch of the Ganga from Buxar to Barh is moderately polluted and the degree of pollution is greater near Patna. After receiving a heavy load of pollutants near Patna the river again recovers to great extent near Barh. The population ot benthic macroinvertebrates was less during the monsoon season which may be attributed to fast current in the river which disturbs the bottom sediments. Hughes observed that sampling method, the area sampled, the time of year as well as the level of identification influenced the diversity index. Therefore, extreme care is needed in the interpretation of diversity indices.

II. Indicator Bacterial Count

Bacteria are considered good indicators of organic pollution. The occurrence and distribution of human pathogenic bacteria in aquatic environment can be measured indirectly by means of 'indicator' accompanying organisms such as total coliform, faecal streptococci, *Escherichia coli* and others. A detailed bacteriological study was made at Sultanganj (bathing ghat and downstream) and Bhagalpur (Sewage mixing point and downstream of river Ganga). At Sultanganj bathing ghat the maximum value of total coliform and faecal streptococci recorded 3,20,000/ 100 ml and 9,600/100 ml respectively during rainy season is attributed to heavy input of faecal and other organic matter due to intense human activity and bathing by millions of people at that time (Table 12.5, p. 77). At Bhagalpur maximum MPN of total coliform and faecal streptococci (2,40,000 and 7,200/100 ml respectively) at sewage discharge point was recorded during rainy season, while the lowest density was recorded to be 2,800 and 7,80/100 ml down the stream during winter and summer respectively. Bacterial contamination was always higher at sewer mixing zone and this affects the water quality at down the stream, to a distance of about 500 metres. Bacterial concentration in this range was substantially higher than that at the upstream point.

III. Pollution Tolerant/Sensitive biota

Physiological or behavioural responses of aquatic organisms exposed to pollutants serve as important indicators of the environment. Indicators occurring or existing in polluted environment are supposed to accumulate toxic substances and suffer physiological stress i.e., diminished rate of growth, impaired reproductive capacity or modified behaviour etc. However, another group of organisms which are very sensitive to the exposure of pollutants disappear quickly and their reduction in number finally change the species composition/diversity at the affected site. Some of the indicator organisms which have been identified at Bhagalpur are as follows :

Algae

A detailed qualitative and quantitative study of algae at sewage disposal site of river Ganga at Bhagalpur was done to sort out such algae which could be used as indicators of organic pollution. The density of each algal species was calculated and algae were broadly categorised in four groups on the basis of their frequency of occurrence and abundance. The sensitivity and tolerance capacity of algae vary with the change in prevailing physico-chemical set up of the water due to input from sewers as shown in Table 18.3. A remarkable change in the number and density of specific algal forms was noticed at different sites. On the basis of these changes total forms are categorised into three groups: (i) those algal forms which were confined to sewage discharge and mixing points only and were never recorded from upstream; these may be treated as pollution tolerant forms and included *Oscillatoria chlorina, O. tenuis, Phormidium uncinatum, Spirulina major, Chlorella vulgaris, Ankistrodesmus falcatus, Schizomeris leibleinii, Stigeoclonium tenue, Euglena acus, E. viridis, Navicula viridula* (Table 18.3), (ii) On the contrary there was another group whose algae were highly sensitive to toxic pollutants and were encountered only in clean habitat (i.e. upstream); these pollution sensitive algae disappeared the moment composite sewage effluents

TABLE 18.3

Qualitative and Quantitative Enumeration of Algae of the River Ganga at Sewage Disposal Site of Bhagalpur during 1986–1987

Algae	Upstream	Sewage Discharge	Mixing Zone	Downstream
Cyanophyta				
Oscillatoria subbrevis	4 +			+
O. chlorina		3 +	2 +	
O. formosa	2 +			+
O. tenuis		4 +	2 +	
O. limosa		2 +	+	+
Phormidium calcicola	+			+
P. uncinatum		2 +	+	+
Anabaena laxa	3 +			2 +
A. fertilissima	3 +			
Nodularia spumigena	2 +			
Merismopedia glauca	2 +			+
M. punctata	2 +		+	+
M. elegans	2 +			
Microcystis aeruginosa		2 +	+	+
Anabaenopsis arnoldii	+			+
Gloeocapsa sp.				2 +
Lyngbya magnifica	2 +			
L. gracilis	2 +			
Spirulina major		4 +	2 +	
Chlorophyta				
Hydrodictyon reticulatum	2 +			3 +
Coelastrum microporum	+		+	
Pediastrum simplex	+		+	
P. duplex	+			+
P. tetras var. *exiisum*				+
Cladophora glomerata	+			+
Chlorella vulgaris		3 +	2 +	
Ankistrodesmus falcatus			2 +	+
Scenedesmus quadricauda		+	+	+
Schizomeris leiblinii		2 +	+	
Stigeoclonium tenue		+		
Closterium acerosum		2 +	+	+
Chlamydomonas mirabilis	+			+
Cosmarium tenue	+			
C. dentiferum				
Dictyosphaerium pulchellum	+		+	
Oedogonium crassum	+			+
Spirogyra subsalsa	+			
S. affinis	+			+
Tetraspora gelatinosa	+			
Euglenophyta				
Euglena acus		2 +	+	
E. viridis		+	+	
Phacus caudatus		2 +	+	
P. viridis		+		+
Bacillariophyta				
Synedra ulna		3 +	+	
S. acus	+			+
Navicula viridula		+	+	
N. gracilis	+			+
Melosira ambigua	+		+	+
Cymbella turgidula	+			
C. turgida	+			+
Amphora sp.	+			
Fragilaria sp.	+			+
Gyrosigma sp.	+			+
Gomphonema constrictum	+			+
G. parvulum				+
Hantzschia sp.				+
Nitzschia acicularis	+			+
N. palea				+
Pinnularia interrupta	+			

+ = (1–25 u/l); 2+ = (26–50u/l); 3+ = (51–75u/l); 4+ = (76 or more u/l).

get mixed with the river water and included *Anabaena fertilissima, Nodularia spumigena, Merismopedia elegans, Lyngbya magnifica, L. gracilis, Cosmarium tenue, Dictyosphaerium pulchellum* and *Spirogyra subsalsa*. (iii) The third group of algae comprising a large number of species from different classes did not show any consistent behaviour to changed environmental set up; these forms were recorded from upstream, mixing zone, downstream and sometimes from sewage sites also (Table 18.3) in varying concentration; such algae may not be reliable as indicators, due to their tolerance for a wide range of habitats.

Zooplankton

Rotifers were found to be useful indicators of organic pollution.

PROTOZOA : *Paramecium caudatum* was recorded from the polluted zones of the river Ganga. They were absent from the clean zone i.e. upstream or mainstream of the river Ganga.

CLADOCERA : *Moina brachiata* was recorded abundantly from the area of sewage discharge in the river.

ROTIFERA : Many species of rotifers were found to be pollution tolerant. Their number were more in the areas of sewage discharge in the river. A list of pollution tolerant zooplankton has been presented in Table 18.4.

TABLE 18.4

Pollution Tolerant / Indicator Species of Zooplankton of the River Ganga at Bhagalpur

Phylum order	Species composition
PROTOZOA	*Paramecium caudatum*
ROTIFERA	*Brachionus rubens* *B. angularis* *B. plicatilis* *B. quadridentata* *B. calyciflorus* *Platiyas polyacanthus*
CLADOCERA	*Moina brachiata*

Benthic Macroinvertebrates

Benthic organisms are valuable indicators of past and present water quality because of their long life history. Benthic fauna of the river Ganga was analysed from various stations between Munger to Farakka and attempts were made to identify the pollution tolerant species. Some species were found to be mostly or entirely inhabiting polluted water. These were *Tubifex*, *Nemalycastis indica*, *Nephtys oligobranchia*, Chironomous larvae, *Corixa* sp., *Thiara tuberculata and Bellamya bengalensis*. Among the above described species members of Oligochaeta (*Tubifex* sp.) and Polychaeta (*Nemalycastis indica* and *Nephtys oligobranchia*) were entirely confined to polluted water in an area where town sewage meets the river.

From Buxar to Barh the following zooplankton were found to be indicators of industrial/urban pollution. *Polyarthra* sp., *Monostyla* sp., *Filinia terminalis*, *F. longiseta*, *Keratella cochlearis*, *Brachionus caudatus*, *B. rubens*, *B. quadridentata*, *B. angularis* and *B. calyciflorus*. Besides these zooplankton some species of benthic macroinvertebrates have been identified as pollution indicators *i.e.* *Tubifex* sp., *Limnodrilus hoffmeisteri*, Dragon fly nymph, Chironomus larvae and *Lymnaea* sp. Between Mirzapur to Ballia 17 algal species were collected from highly polluted sites. These are listed in Table 18.5.

The phytoplankton density varies in different ecoregions of the Ganga from Gangotri/Badrinath to Bally in West Bengal. In the upper stretch of the river the phytoplankton density was low and dominated by members of Bacillariophyceae, whereas the maximum density was recorded in the middle stretch mostly dominated by the Bacillariophycean members. A gradual increase in phytoplankton density was noticed as the river flows down from the hill to plains touching the highest peak in between Mirzapur to Ballia. The phytoplankton density again declined. The phytoplankton diversity was also maximum in the middle zone from Kannauj to Farakka. 725 species were encountered in this region. In the upper (Gangotri/Badrinath to Garhmukteshwar) and lower (Berhampur to Bally) stretches only 106 and 77 species respectively were recorded. Kannauj to Farakka range is important from the point of view of algal density and diversity. A long span, rich nutrient load, wider bed and moderate water current etc. possibly contribute to this diversity.

TABLE 18.5

List of Algae Recorded in the Ganga at Different Sites from Mirzapur to Ballia

Algae recorded at highly polluted sites

(Total number of genera 11 and 17 species)
(September 1986 to August 1987)

CHLOROPHYCEAE	:	*Chlamydomonas mirabilis*, *Scenedesmus quadricauda*
BACILLARIOPHYCEAE	:	*Amphora veneta*, *Gomphonema clevei*, *G. parvulum*, *Navicula minima*, *Nitzschia communis*, *N. thermalis*, *N. palea*, *Synedra ulna*.
CYANOPHYCEAE	:	*Oscillatoria subbrevis*, *O. tenuis*, *Spirulina major*
EUGLENOIDAE	:	*Euglena acus*, *E. viridis*, *Phacus acuminatus*, *P. pusillus*

Seasonal fluctuations have a profound impact on phytoplankton density and diversity. In general, the density was maximum in summer. During the rainy season there was a sharp fall in density which again showed an upward swing from November onwards touching a second peak of lesser magnitude in the month of December. In the hilly region however, i.e. Gangotri to Rishikesh the phytoplankton density was highest in winters and lowest in monsoons.

Zooplankton density and diversity did not present any definite trend. Maximum substantially high Zooplankton density was recorded in the stretch between Rishikesh to Garhmukteshwar while the diversity was highest between Munger to Farakka. The zooplankton density in the Bhagalpur region had a bimodal peak. Their density was maximum in summer followed by winter and the rainy season. The first peak of higher magnitude was recorded in the month of May while the other peak of lesser magnitude was recorded in the month of January.

Concentration of bacterial density and MPN of total coliform organisms in the Ganga shows fairly wide seasonal and sectoral variations. Even at the same spot the bacterial density varied with the depth of river, distance from the bank, speed of current and human activities etc. Level of organic load had maximum impact on bacterial density. The population density of coliform and other enteropathogens increases significantly during the summer and rainy seasons touching highest peak in July/August (Coliform 9,950 to 9,20,000/100 ml). Level of bacteria during the winter is comparatively low (Coliform 12 to 700/100 ml). Maximum concentration of total coliform was recorded from Kalakankar to Phaphamau during the rainy season (9,20,000/100 ml). Zone between Gangotri to Rishikesh had a very low density of coliform bacteria (12/100 ml). With regard to total bacterial density maximum value was recorded in rainy season between Barh to Sultanganj (1100 × 10^6/L) and minimum from Badrinath to Narora (0.011 × 10^6/L).

Fungal species diversity was maximum between Munger to Farakka and minimum in upper stretch of the Ganga i.e. Rishikesh to Garhmukteshwar.

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19

Macrophytic, Marginal and Riparian Vegetation of the Ganga

K. S. BILGRAMI

Macrophytes constitute the marginal vegetation growing on the bank of rivers. Some of the macrophytes are ecologically and economically very important. The macrophyte vegetation keeps on changing due to floods, changing water level thus, influencing the pattern of marginal vegetation. Some of the soil binder plants which are encountered throughout the stretch of the Ganga include *Saccharum spontaneum, Ipomoea carnea, Lantana camara, Imperata cylindrica, Cynodon dactylon* and *Dichanthium annulatum*. Some important shrubs are also common on sandy bed and in the Diara region. Although macrophytes do not play any major role in primary production in river ecosystems, they provide shelter to breeding animals and fishes.

The macrophytes comprised aquatic and semi-aquatic vegetation. Plants from riparian vegetation are also recorded in Varanasi range. Some of these are very helpful in conservation of water and nutrients. They also minimize the adverse effects of pollutants. List of the plants constituting macrophyte, marginal and riparian vegetation is given in Table 19.1. The list has been compared with the check list prepared by the Botanical Survey of India (BSI).

At Varanasi, the species content, dispersal and density structure of riparian vegetation was studied. It was found that the riparian vegetation acts as a significant conserver of water, nutrient, soil and pollutants that run through the slope of the river bank. Thus, these plants help in prevention of river pollution, siltation, upwelling of river bed and minimize the adverse effects of floods to a considerable extent. Work has been done on quantitative measurements with regard to exact quantity that each species conserves within the sloping-soil ecosystem through its vegetational cover. The dicot weeds *Xanthium strumarium* and *Phyla nodiflora* were found to reduce soil erosion on a 10° slope prepared from the Ganga bank soil to the extent of 50-60 per cent and 85-95 per cent respectively. The seedlings of *Imperata cylindrica* and *Ricinus communis* show soil conservation with probable value around 60 and 45 per cent respectively. It is expected that with the maturity of the plants on the experimental slopes, the conservation percentage may increase above 80 per cent. Further, the fast growing N_2 fixing short tree of *Leucaena leucocephala* has been successfully planted on slopes of water bodies and experimental plots for measurement of their conservation values. The grasses like *Saccharum spontaneum, Cynodon dactylon, Cyperus rotundus* are also being studied for their conservation value (Table 19.1).

Effect of paper mill and rubber effluents on macrophytes were examined by Kalyani University. Data were collected from 3 sites such as site 1 (100 mt. downstream from the point of discharge), site 2 (100 mt. upstream from the discharge point) and site 3 (opposite the bank). It was observed that total number of species, density and abundance for each macrophyte species of site 3 was higher than sites 1 and 2 except certain species such as *Polygonum hydropiper, Alternanthera* sp. and *Amaranthus spinosus*. Comparison of morphological data such as length of internode, petiole and size of leaf indicated that the data of site 3 were of higher magnitude than sites 1 or 2, except the species mentioned above. The impact of pollutants on percentage seed germination of some selected macrophytes were also studied and it was observed that the percentage seed germination of all the species were higher in control (except *Brassica juncea*) than that of the effluent exposed plants from Naihati Jute Mill. In the same way the percentage of seed germination was higher in control (except *Amaranthus tricolor*) as compared to effluent exposed plants from paper mill. In both the effluents not only there was decrease in the rate of percentage seed germination but also in the rate of survival after germination. From the above studies it may be concluded that the diversity of macrophytic vegetation on the river banks as well as in Diara lands was substantially affected by industrial pollutants. The pollution effect was not pronounced on certain plant species and

TABLE 19.1

List of the Aquatic Macrophytes and Marginal Plants and those Constituting Riparian Vegetation (the lists prepared by some centres are partial. 'M' refers to such plants which are of medicinal value)

Names of Plants with local Indian name in brackets	ECOREGIONS						
	Upper	Middle					Lower
	0113	0122	0123	0124	0126	0134	0132
	Gurukul Kangri Univ.	Rae Bareli Univ.	B.H.U.	Patna Univ.	Bhagalpur Univ.	Calcutta Univ.	Kalyani Univ.
	(Rishikesh to Garhmukteshwar)	(Kalakankar to Phaphamau)	(Mirzapur to Ballia)	(Buxar to Barh)	(Munger to Farakka)	(Bandel to Bally)	(Katwa to Chinasura)
	I	II	III	IV	V	VI	VII
TREES							
1. *Acacia catechu* (Catha)	M+				+		
2. *A. nilotica* (Babul)	+				+		
3. *Aegle marmelos* (Bel)	M+				+		
4. *Amoora rohituka*	+				+		
5. *Averrhoa carambola* (Kabaranga)	+				–		
6. *Azadirachta indica* (Neem)	M+				+		
7. *Buchanania lanzan* (Piar)	+				–		
8. *Barringtonia acutangula*	M+				+		
9. *Cassia fistula* (Amaltas)	M+				+		
10. *Crataeva nervala* (Varun)	M+				–		
11. *Emblica officinalis* (Amla)	M+				+		
12. *Flacourtia* sp. (Paniyala)	+				+		
13. *Gmelina arborea* (Gamhar)	M+				–		
14. *Mangifera indica* (Am)	+				+		
15. *Mollotus philippensis* (Sinduri)	+				+		
16. *Moringa oleifera* (Sahajan)	M+				+		
17. *Pongamia pinnata* (Karanj)	M+				+		
18. *Quercus* spp.	+				+		
19. *Stereospermum suaveolens* (Padar)	+				+		
20. *Syzygium cumini* (Jamun)	M+				+		
21. *Tecomella undulata*	+				–		
22. *Terminalia arjuna* (Arjun)	M+				+		
23. *Terminalia bellirica* (Bahera)	M+				–		
24. *T. chebula* (Hare)	M+				–		
25. *Vitex negundo* (Sindwar)	M+				+		
26. *Tamarix dioica* (Jahu, Jhaua)					+		

(*Contd.*)

TABLE 19.1-*Contd.*

	I	II	III	IV	V	VI	VII
27. *Oroxylum indicum*	M				+		
28 *Trewia nudiflora*					+		
29. *Excoecaria agallocha*					+		
30. *Hibiscus tiliaceus*						+	
31. *Dalbergia sissoo*						+	
CLIMBERS							
1. *Asparagus* spp. (Satawar)	M +				+		
2. *Bryonopsis laciniosa* (Pachguria)	+				+		
3. *Cissampelos pareira* (Akandi)	M +				+		
4 *Dioscorea bulbifera* (Khamarua)	M +				+		
5. *Hemidesmus indicus* (Anantmul)	M +				+		
6. *Ichnocarpus frutescens* (Dudhilata)	M +				+		
7. *Leptadenia reticulata*	+				+		
8. *Pueraria tuberosa* (Patalkohra)	M +				+		
9. *Tylophora indica*	M +				+		
10. *Cuscuta reflexa* (Amarbel)	M	+			+		
11 *Tinospora cordifolia* (Gorich)	+				+		
12. *Celastrus paniculatus*	M				+		
13. *Dalbergia spinosa*						+	
14. *Derris trifoliata*							+
15. *Mikania cordata*							+
16. *Ipomoea cairica*							+
17. *I. sepiaria*							+
SHRUBS							
1. *Adhatoda zeylanica* (Vakash)	M +	+		+	+		
2. *Barleria* spp	+				+		
3. *Barleria prionitis* (Bajradanti)	+	+			+		
4. *Cassia sophera*							+
5. *Calotropis gigantea* (AK)	M +				+		
6. *Abelmoschus esculentus* (Bhindi)	+				+		
7 *Hibiscus rosasinensis* (Arhul)	+				+		
8 *Plumbago zeylanica* (Chitrak)	M +				+		
9. *Rouwolfia serpentina* (Sarpgandha)	M +				+		
10. *Solanum khasianum*	M +				+		
11. *S. indicum*	M +				+		
12. *S. torvum*	+				+		
13. *S.enanthum* (Arus)	+				+		
14. *Vernonia anthelmintica* (Sorai)	M +				+		
15. *Cassia occidentalis* (Chakora)	M	+			+		

(*Contd.*)

TABLE 19.1 - *Contd.*

		I	II	III	IV	V	VI	VII
16.	*Calotropis procera* (AK)	M	+	+		+		
17.	*Withania somnifera* (Asgandh)	M	+			+		
18.	*Lantana indica* (Putus)		+			−		
19.	*Jatropha curcas* (Bagandhi)	M	+			+		
20.	*Clerodendrum inerme*	M		+	+	+		
21.	*Datura* sp. (Dhatura)			+	+	+		
22.	*Abutilon indicum* (Khanghi)	M			+	+		
23.	*Datura metel* (Dhatura)	M			+	+		
24	*Lippia javanica*				+	+		
25.	*Lantana camara* var. *aculeata* (Putus)			+	+	+		
26.	*Jatropha gossypifolia* (Lalbaghandi)					+	+	+
27.	*Leonurus sibiricus*					+		
28.	*Polyalthia suberosa* (Burhichamri)					+		
29.	*Caseana tomentosa* (Chorcho)					+		
30.	*Barleria cristata*					+		
31.	*Mallotus repandus*					+		
32.	*Acanthus ilicifolius*						+	
33.	*Caesalpinia crista*	M						+
34.	*Glycosmis arborea*							+
35.	*Kirganelia reticulata*							+
36	*Urena lobata*							+
HERBS								
1.	*Acorus calamus*							
2.	*Achyranthes aspera* (Chirchiri)	M +	+	+	+	+		
3.	*Artemisia* sp.	+						
4.	*Asclepias* sp.	+						
5.	*Boerhavia diffusa* **(Punarnabha)**	M +	+	+	+	+		
6	*Celosia argentea* (Murgaful)				+	+		
7	*Catharanthus roseus* (Sadasuhagan)	M +				+		
8.	*Centella asiatica* (Brahmai)	M +				+		
9.	*Costus speciosus*	+				+		
10.	*Cynoglossum lanceolatum*	+				+		
11	*Desmodium gangeticum* (Prinparni)	M +				+		
12.	*Eclipta prostrata* (Bhangrya)	M +	+	+	+	+		
13.	*Ocimum sanctum* (Tulsi)	M +				+		
14.	*Pedalium murex* (Gokhru)	M +				+		
15.	*Psoralea corylifolia*	M +				+		
16	*Sida cordata* (Bariyar)	M +				+		
17	*S. cordifolia* (Bariyar)	M +				+		

(*Contd.*)

TABLE 19.1 – *Contd.*

		I	II	III	IV	V	VI	VII
18.	*S. obovata* (Bariyar)	+						
19.	*S. rhombifolia* (Bariyar)	+	+			+		
20.	*Solanum surattense* (Rengahi)	+				+		
21.	*Tribulus terrestris* (Gokhru)	M +	+			+		
22.	*Trianthema portulacastrum* (Pindua)	+				+		
23.	*Uraria picta* (Prishnparni)	M +				+		
24.	*Ranunculus sceleratus* (Jaldhania)		+			+		
25.	*Argemone mexicana* (Peelakatya)		+			+		
26.	*Coronopus didymus*		+			+		
27.	*Polygala erioptera*		+					
28.	*Polycarpon prostratum*		+	+		+		
29.	*Portulaca quadrifida* (Nuneasag)		+			+		
30.	*Bergia ammannioides*		+		+	+		
31.	*Malva parviflora*		+					
32.	*Malvastrum coromandelianum*		+		+	+		
33.	*Alysicarpus vaginalis*		+			+		
34.	*Crotalaria medicaginea*		+	+		+		
35.	*Desmodium triflorum*		+		+	+		
36.	*Indigofera linnaei*	+	+			+		
37	*Indigofera linifolia*		+			+		
38.	*Lathyrus sativus* (Khesari)		+			+		
39	*Medicago polymorpha*		+			+		
40	*Melilotus alba*		+		+	+		
41	*Melilotus indica*		+	+	+	+		
42	*Phaseolus trilobus*		+			+		
43	*Vicia sativa* (Akari)		+			+		
44	*Ammannia baccifera*	+				+		
45.	*Potentilla supina*	+				+		
46	*Glinus lotoides*	+				+		
47.	*Oldenlandia corymbosa*	+				+		
48.	*Ageratum conyzoides*	+	+	+	+	+		
49	*Blainvillea acmella*		+	+		+		
50	*Blumea amplectens*		+					
51	*Echinops echinatus*		+			+		
52.	*Grangea maderaspatana*		+			+	+	+
53.	*Launaea asplenifolia*		+	+		+		
54.	*Pulicaria crispa*		+			+		
55.	*Tridax procumbens* (Jhurijhuri)		+	+	+	+	+	+
56	*Vernonia cinerea*		+			+	+	+
57	*Anagallis arvensis*		+			+		
58.	*Primula umbellata*		+			+		

(*Contd.*)

TABLE 19.1 - *Contd.*

	I	II	III	IV	V	VI	VII
59. *Canscora decussata* (Katchireta)		+			+		
60. *Heliotropium indicum* (Hatisurh)		+			+		
61. *Evolvulus alsinoides*		+			+		
62. *Nicotiana plumbaginifolia* (Janglitamaku)		+		+	+		
63. *Physalis minima* (Makao)		+			+		
64. *Solanum nigrum* (Puthka)		+	+	+	+		
65. *Lindemia crustacea*		+	+		+		
66. *Mazus pumilus*		+		+	+		
67. *Scoparia dulcis* (Meethapati)		+	+	+	+		
68. *Polygonum hydropiper*							+
69. *Verbascum thaspus*		+					
70. *Justicia simplex*		+	+		+		
71. *Peristrophe bicalyculata*		+			+		
72. *Rungia pectinata*		+			+		
73. *Alternanthera philoxeroides*							+
74. *Anisomeles indica*		+			+		
75. *Leucas aspera* (Gumma)		+			+		
76. *Ocimum canum* (Bantulsi)		+			+		
77. *Salvia plebeia*		+		+	+		
78. *Alternanthera pungens*		+			+		
79. *A. sessilis* (Serouchi)		+		+	+		
80. *Amaranthus spinosus* (Katylasag)		+			+	+	+
81. *A. viridis* (Janglisag)		+		+	+		
82. *Digera muricata*		+			+		
83. *Gomphrena celosioides*		+			+		
84. *Chenopodium album* (Bathua)		+	+	+	+	+	+
85. *Polygonum glabrum*		+			+	+	+
86. *P. plebeium*		+			+		
87. *Rumex dentatus*		+	+	+	+		
88. *Acalypha indica*		+			+	+	+
89. *Chrozophora rottleri*		+	+	+	+		
90. *Cannabis sativa* (Bhang)		+		+	+		
91. *Croton bonplandianum* (Mirchaini)		+	+	–	+		
92. *Asphodelus tenuifolius* (Jangalipyaj)		+			+		
93. *Commelina bengalensis* (Kenasag)		+	+		+		

(*Contd.*)

TABLE 19.1 – *Contd.*

		I	II	III	IV	V	VI	VII
94.	*C. nudiflora*		+			+		
95.	*Argemone mexicana*			+	+	+		
96.	*Alhagi pseudoalhagi*			+		+		
97.	*Convolvulus microphyllus* (Sankhpushpi)			+		+		
98.	*Cassia tora* (Chakora)			+		+		
99.	*Cyanotis axillaris*			+	+	+		
100.	*Euphorbia thymifolia* (Chotadudhi)			+		+		
101.	*Phyllanthus fraternus* (Hazardana Bhuiamla)							
102.	*Depteracanthus prostratus*			+		+		
103.	*Convolvulus arvensis*			+		+		
104.	*Lindenbergia indica*			+		+		
105.	*Ricinus communis* (Andi)			+		+		
106.	*Xanthium strumarium*			+	+	+		
107.	*Scirpus articulatus*					+		
108.	*Cleome viscosa* (Peelahurhur)				+	+		
109.	*Cleome gynandra* (Swethurhur)				+	+		
110.	*Portulaca oleracea* (Kulpsag)				+	+		
111.	*Polygonum orientale*							+
112.	*Sida acuta* (Bariyar)				+	+		
113.	*Corchorus acutangulus*				+	+		
114.	*Oxalis corniculata* (Tinpatiya)				+	+		
115.	*Alysicarpus monilifer*				+	+		
116.	*Scoparia dulds*							+
117.	*Oldenlandia diffusa*				+			
118.	*Parthenium hysterophorus* (Saphedtopi)				+	+		
119.	*Volutarella divaricata*				+	+		
120.	*Caesulia axillaris*				+	+		
121.	*Heliotropium hirsutum*				+	+		
122.	*Evolvulus alsinoides*				+	+		
123.	*Mecardonia procumbens*				+	+		
124.	*Chrysopogon aciculatus*							+
125.	*Hydrolea zeylanica*							+
126.	*Hygrophila auriculata*					+		+

(*Contd.*)

TABLE 19.1 - *Contd.*

	I	II	III	IV	V	VI	VII
127. *Amaranthus spinosus*					+		+
128. *Euphorbia rosea*				+			
129. *Phyllanthus simplex*				+	+		
130. *Phyla nodiflora*					+	+	+
131. *Nasturtium indicum*					+	+	+
132. *Murdannia nudiflora*					+		
133. *Nepeta hindostana*					+		
134. *Wedelia calendulacea* (Mahabhiringraj)						+	+
135. *Oldenlandia paniculata*					+		
136. *Erigeron asteroides*					+		
137. *Verbascum chinense*					+		
138. *Justicia peploides*					+		
139. *Hibiscus vitifolius*					+		
GRASSES							
1. *Cynodon dactylon* (Dubgrass)			+	+	+		+
2. *Dichanthium annulatum*				+	+		
3. *Saccharum spontaneum* (Kans)				+	+		
4. *Panicum repens*				+	+		
5. *Setaria verticillata*				+	+		
6. *Paspalum distichum*				+	+		
7. *Hygroryza aristata*						+	+
8. *Imperata cylindrica*					+		
SEDGES							
1. *Cyperus rotundus* (Motha)	M						
2 *Scirpus articulatus* (Pati)			+	+	+		
3. *Kyllinga brevifolia*			+	+	+		
4. *Scirpus maritimus*					+		
5. *Fimbristylis dichotoma*					+	+	
MACROPHYTES							
1. *Pistia stratiotes* (Chotajalkhumabhi)	+	+			+		
2. *Lemna paucicostata*(Duckweed)		+			+		
3. *Spirodela polyrhiza* (Titali)		+			+		
4. *Ceratophyllum demersum*		+			+		
5. *Potamogeton crispus*		+			+		

(*Contd.*)

TABLE 19.1 - *Contd.*

	I	II	III	IV	V	VI	VII
6. *Eichhomia crassipes* (Jalkhumbi)			+		+		
7. *Potamogeton pectinatus*			+		+		
8. *Eleocharis palustris*			+		+		
9. *E. dulcis*			+		+		
10. *Hydrilla verticellata*			+		+		
11. *Aponogeton natans*			+		+		
12. *Scirpus articulatus*			+		+		
13. *S. maritimus*							
14. *Trapa bispinosa* (Singhara)					+		
15. *Najas graminea*					+		
16. *Ottelia alismoides*					+		
17. *Marselia minuta* (Charaatya)					+		
18. *Equisetum* sp.					+		
19. *Zannichellia palustris*					+		
20. *Vallisneria spiralis*					+		
21. *Sagittaria sagittifolia*					+	+	+
22. *Azolla pinnata*					+		
23. *Chara* sp.					+	+	+
24. *Nitella* sp.							
25. *Typha* sp. (Elephant grass)				+	+	+	+
26. *Cyperus* sp.					+	+	+
27. *Aponogeton crispum*					+		
28. *Sagittaria guayanensis*					+		
29. *Potentilla supina*					+	+	
30. *Potamogeton nodosus*					+		
31. *Pistia stratiotes*				+	+		
32. *Jussiaea repens*				+	+	+	

these plants may be regarded as resistant or tolerant. Such plants may be exploited as tools in biocontrol of pollution.

Using *Hydrilla, Azolla* and *Eichhomia* as test plants by the team of Burdwan University, it was observed that their growth (dry weight) in the Ganga water was generally correlated to its nutrient content. Results revealed that growth of the test plants in Ganga water samples resulted in depletion of nutrients in water, reduction of TSS and BOD and a shift in *p*H towards alkalinity. *Eichhomia* was found to be most efficient in causing such change, though *Azolla* preferentially removed more phosphorus than the other two. *Eichhornia* required the minimum retention time among the three for removal of key nutrients form the growth medium, followed by *Azolla* and *Hydrilla*. During a detailed study of aquatic plants of medicinal and antipollutant value of the river Ganga between Mirzapur to Ballia altogether 33 genera and 80 species were collected from different sites. *Ipomoea aquatica, Sesbania sesban* and *Trapa bispinosa* show highest rate of extractability of leaf protein with five or six essential amino-acids (EAA) which show a significant value of utilization as a byproduct of extraction of leaf protein concentrate.

Observations on the mineral component in leaf and leaf protein concentrates in plants like *Hydrilla verticillata, Trapa bispinosa, Ludwigia adscendens, Tephrosia purpurea* etc. indicate a good scope of their exploitation as food mineral supplements.

In order to evaluate the suitability of different tree species for the cultivation in flood prone areas of Hugly river, planting was done on the banks of the river at six different locations between Chakdah in north and Budge Budge in south. Out of 28 tree species only 14 species showed good growth potential under flood inundated and erosion prone areas. These are as follows : *Leucaena leucocephala, Terminalia arjuna, Acacia auriculiformis, Samanea saman, Cassia siamea, Delonix regia, Eucalyptus* spp., *Lagerstroemia speciosa, Pongamia pinnata, Gliricidia* sp., *Azadirachta indica, Sweitenia mahogani, Bauhinia purpurea, Putranjiva roxburghii.*

20

Integrated Study of the Ganga Ecosystem between Narora and Kannauj (U.P.)

A.M. SIDDIQI

An integrated study of the Ganga ecosystem between Narora and Kannauj (U.P.) between May 1, 1987 to March 31, 1990 was carried out by seven research groups in six departments of the Aligarh Muslim University : Applied Chemistry, Biochemistry, Botany, Civil Engineering, Geography and Zoology. The research activities of the groups were coordinated by the GANGA WATER POLLUTION COORDINATION CELL created in the University, under the patronship of the Vice Chancellor and Co-Principal Investigators as members of the cell. Results are summarized in the following pages.

Water Quality

The physical and chemical characteristics of water did not show any marked change during the period of study (October 1987 to March 1990).

Inter-relationship Between Parameters

In determining the inter-relationships between parameters,TDS and COD were considered as primary (independent) and others such as EC, calcium, sodium, chloride, sulphate, carbonate, bicarbonate, BOD as secondary (dependent).

Statistical analysis of data from individual stations and the clubbed data showed that there was significant correlation between primary and secondary parameters. It was also noted that the relationship between a pair of parameters was not much different from data of one station to another eventhough the range of magnitude of values differed. Therefore, in order to increase the reliability of correlations and to decrease the number of regression equations, it was decided to fit a single curve between any two parameters for the entire length of river for all seasons.

A mass balance between TDS and sum of all major ions which were determined was made for all observations.

It is seen that total ions as measured exceed the TDS value most of the time. This discrepancy is 10 to 30 per cent. The balance is acceptable considering various sources of error such as, dissolution/precipitation of dissolved substances during transport and storage of samples, loss of carbon dioxide from bicarbonate in measurement of TDS etc.

Trends in Water Quality Changes in the Study Reach

A slight increase in salt concentration was noted at Kannauj. However, the concentration was quite low to cause impairment of water quality.

DO of the river in the entire reach was nearly always above 6mg/l, the lower limit for classification of the river as 'A' class river.

The BOD of the river water at various stations, was studied. A gradual increase from about 4mg/l at Narora to 7mg/l at Kannauj was noted. A number of observations at Narora and Katchla showed BOD values in the range of 2 to 3mg/l indicating a high water quality of class A to B. However, the BOD values at Fatehgarh and Kannauj were most of the time higher than 5mg/l indicating organic pollution and deterioration of water quality to class C and D.

Heavy Metal Load

A class of pollutants requiring particular attention in the aquatic environment is heavy metals which depend upon hydrogeology of the river stretch. In addition, heavy metals enter the aquatic system by direct discharges of industrial and urban effluents and surface run off. Some heavy metals such as Cd, Cu, Cr and Pb are highly toxic even at lower concentrations. Based on a set of simple criteria related to the occurrence, the natural concentration, release pattern and toxicity of metals following priority classification is given below:

High priority Group	Hg, Cd
Medium priority Group	Cr, Cu, Ni, Pb
Low priority Group	Fe, Mn, Zn

The concentration of ten heavy metals viz. Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn of all the stations for the period of October, 1987 to March, 1990 shows the permissible limits of these metals in drinking water. Comparison of quality of these metals permitted in drinking water with those occurring in river water sample shows that most of the metal concentrations were lower except Hg, Fe, and Pb. Higher values of Hg, Fe and Pb are probably due to absorption of metals on the suspended particle in the water. The heavy metal concentration in the reach, therefore, are within the safe levels.

Microbiological and Biochemical Analysis

Bacteriological Quality of Water : *Salmonella* was only found once at Narora during Monsoon, 1989. In addition to four seasons extra sampling was done during the Monsoon of 1988-89 at Narora and Katchla to see the sweeping effect of Monsoon. During Summer 1988 as well as 1989 the total bacteriological count was higher when compared with other seasons. The bacteriological parameters showed much variations. The average coefficient of variation for total bacterial count during Monsoon 1987 to Spring 1990 was 53.3% at Narora and Katchla but 43.3% at Fatehgarh and Kannauj, respectively. The variation in total coliform data was 83.3% at Narora, 66.7% at Katchla, 103.3% at Fatehgarh and 116.7% at Kannauj. The faecal coliform variation was 138.7% at Narora, 120% at Katchla and Fatehgarh and 113.3% at Kannauj. The variation in faecal streptococci data was to the extent of 109.3% at Narora, 80% at Katchla, 100% at Fatehgarh and 73.3% at Kannauj.

The mid-stream values, as expected always showed decreasing trend than marginal water except in a few seasons at different sampling stations as indicated. During Summer 1989 the total bacterial count of mid-stream water at Katchla was almost equal to marginal water which was reflected in higher faecal streptococci values. At the same station the faecal streptococci was significantly higher in mid-stream than marginal water. The faecal streptococci value at Fatehgarh in marginal water in summer 1989 was equal to mid-stream value even though the total bacterial count was lower. The faecal streptococci values at Kannauj during postmonsoon, 1989 was same in marginal and mid-stream water.

Multiple Drug-Resistance Pattern of Coliform: Multiple drug resistance pattern in the *E. coli* strains isolated at the four sampling stations during June 1988 – November 1988 of the allotted range of Ganga stretch was studied against various antibiotics. From all the sampling stations penicillin, oxicillin, erythromycin, cloxicillin, ampicillin and rifampicin resistant strains have been isolated. A few chloramphenicol and tetracycline resistant *E. coli* strains wêre also isolated. The preliminary studies on the multiple drug resistant *E. coli* strains indicated the presence of plasmids.

Drug resistance pattern in the *E. coli* strains isolated from Narora, Fatehgarh and Kannauj Ganga stretch between January 1989 to March 1989 were tested against various antibiotics. At all the sampling stations, penicillin, erythromycin, cloxicillin, ampicillin, rifampicin, polymixin and nalidixic acid resistant strains have been isolated.

Drug resistance pattern of coliform bacterial strains isolated from the four stations of this stretch of river Ganga were tested against 16 different drugs. All the isolated strains show resistance against ampicillin group of antibiotics in addition to bacitracin, and nitrozolidone. Some isolates were also resistant to chloramphenicol, tetracycline group, nitrofurantonin, neomycin, nalidixic acid, polymyxin-B, streptomycin and sulfadiazine. Some isolates were also resistant to chloramphenicol, tetracycline group of antibiotics, furazolidone, streptomycin and sulfadiazine. It may be again concluded that in this stretch of Ganga coliform bacteria are resistant to almost all antibiotics and sulpha drugs.

Isolation of R-plasmids : R-plasmids were isolated from coliform bacterial strains isolated from the river Ganga.

Cells were harvested from 50 ml of over eight cultures of multiple drug resistant coliform bacterial strains by centrifugation at 7000 rpm for 10 min. in 'Remi' cooling centrifuge. 2 ml reagent A (Tris-EDTA buffer, *p*H 8.0 containing 5% Dow-corning antifoam RD emulsion) was added to the cell pellet. 1.6 ml of this suspension was transferred to 10 ml centrifuge tube. 0.4 ml reagent B (1 M NaOH saturated at 20° C with SDS) was added to this suspension and vortexed for 5 min. 20-40 μl of this suspension was loaded to agarose gel wells and allowed to run for 60 min at 50 mA using TAE (Tris-acetate EDTA buffer, *p*H 8.0) as electrophoresis buffer. The gel was stained by ethidium bromide and observed under UV light on transilluminator (photodyne). Sharp bands of R-plasmid were observed. The gel was then photographed.

Purification of R-plasmids by density gradient centrifugation : 0.7 ml of the crude suspension was layered over 3.3 ml sucrose gradient in 4.0 ml polyallomer centrifuge tubes and allowed to run at 45000 rpm for 60 min at 20° C using SW 60 Ti swing out rotor type in L8-60M model Backman ultracentrifuge. 0.5 ml fractions were collected and loaded on to the 0.8% agarose gel and run at 50 mA for 60 min. The gel was stained by ethidium bromide and bands observed under UV light. Fractions containing less RNA and more plasmid DNA were stored at − 20° C. The gel was photographed.

The molecular size of these R-plasmids was determined by comparing these with lambda-DNA. 30 μl of various plasmid DNA fractions were loaded on to the agarose gel, using lambda-DNA as marker loaded into the first well. The electrophoretic mobility of R-plasmid DNA was found to be almost the same as that of lambda-DNA indicating that the plasmids are of high mol. wt (45 – 50 kb).

Bacterial Conjugation : In order to find out whether R-plasmids are conjugative, R-plasmid harbouring coliforms were mated with *E. coli* (C 600) recipient strains.

0.3 ml of donor (R-plasmid harbouring coliforms) isolated from the river Ganga (amp, tc, lac,) were mated with 1 ml of recipient strains (C 600 amp, tc, lac) for 30 min in boiling tubes containing 1 ml nutrient broth.

Conjugation was terminated by shaking the tubes vigorously and 0.1 ml of this culture was diluted 10 times in 0.01M $MgSO_4$ and 0.1 ml aliquot was spread on the selective media which was MacConkey agar supplemented with 40 μg/ml ampicillin, 20 μg/ml tetracycline and 10 μg/ml streptomycin. Non-pink colonies (non lactose fermenting) were transconjugants scored.

Our conjugation studies suggest that the multiple drug resistant plasmids can also be transmitted to pathogenic bacteria. This is a significant finding but requires more detailed studies to establish its clinical significance with reference to pathogenic organisms.

Mutagenicity Testing : Mutagenicity of water samples against Ames Tester strains TA 97a and TA 102 was done according to standard method of Maron and Ames (1983) as described in METHODS. There was different pattern of mutagenicity against these two strains. But in presence of S9 (Liver microsomal fraction) mutagenicity was decreased, indicating that the metabolites of the mutagens present in water sample are less mutagenic. There is a need to identify the active mutagenic principle(s) of the water of the Ganga river in this stretch.

Residual Pesticide Load : BHC, DDT, Aldrin, Malathion and TDE were detected at high ppb levels at all stations. TDE was only found at Katchla and Kannauj. DDT and Malathion were not found at Fatehgarh and Kannauj. How far these pesticides play a role in mutagenicity of river water remains to be seen. The geographical data support these findings. It is quite likely that analyses of river sediment, ground water and soil of the villages along the river may provide a clearer picture.

Beta-Radioactive Load : So far no beta-activity was found at all the stations more than the background count at all the strategic points of Narora Atomic Power Plant. There is a need to constantly monitor the river stretch for Gross alpha and gamma activity.

Biological Analysis

Mycoflora : In all fifty two different fungi have been isolated from the river Ganga from different stations between post-monsoon season 1987 and spring season 1990. Of these 47 belong to Moniliales and one each of Saprolegniales, Mucorales, Plectascales, Sphaeriales and Sphaeropsidales.

The maximum number of fungal species, i.e. 36 have been isolated during summer seasons of 1988 and 1989, followed by 32 species during spring seasons of 1988, 1989 and 1990. Twenty six species of fungi have been encountered during winter seasons of 1987–88, 1988–89 and 1989–90 while twenty four species during post-monsoon seasons of 1987, 1988 and 1989.

Alternaria species were frequently encountered at all the stations surveyed in the four seasons during the period under report. The frequency of occurrence of *Alternaria alternata* was highest. The fungi belonging to this group have been found more abundant where dead plant parts were decaying. Most of the fungi isolated are known for litter decomposition.

The second most dominant genus found in the river stretch in all seasons at all the sampling stations was *Aspergillus*. The fungi of this group hold an important place amongst cellulose decomposing fungi. The species most frequently encountered are *Aspergillus flavus* and *A. niger*. These two are fast growing saprophytic fungi which grow on organic matter. *Aspergillus* are also known to cause human diseases eg. "Aspergillosis".

Cellulose decomposing fungi belonging to Moniliales (Hyphomycetes) were isolated by using Cellulose Agar medium. Species of *Acremonium, Alternaria, Aspergillus, Cladosporium, Curvularia, Trichoderma and Verticillium* were frequently encountered. Five cellulose decomposing fungi have been isolated in all the sampling stations from 1987 to 1990. They are *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Curvularia lunata* and *Fusarium moniliforme.* The maximum number of fungi were observed between 24 - 29° C. The minimum number of fungi were observed at a BOD of 6 – 8 mg/l.

These could be exploited for early and quick decomposition of organic matter of plant origin lying on the bank of the river at different places and may cause only slow microbial pollution. In freshwater habitats (e.g. Ganga) litter decomposition by fungi is important since protein deficient plant material are converted to microbial biomass which becomes available to primary consumers in food chains and to commercially important fish and crustaceans.

Fusarium species, which is another Moniliales (Hyphomycetes group of fungi) are good indicator organisms of water quality, particularly when polluted with sewage and ground garbage. They may cause mycotic keratitis of eye. According to Shimizu *et al. F. solani* has been utilized in treating cyanide wastes. Species of *Fusarium, Acremonium* and *Trichoderma* occur in river system carrying acid mine drainage (Cooke) and these serve as good indicators. Species of *Fusarium, Trichoderma, Curvularia, Chrysosporium, Verticillium* etc. have the ability to establish themselves in sewage and effluents. This potentiality can be exploited further to produce useful end products. Industrial effluents can possibly be purified and made non offensive by employing some of these fungi. The role of fungi for purifying the river system can be further investigated.

Saprolegniasis is the most common fungal disease of fishes especially the major carps. Species of *Saprolegnia* affect the fertilized eggs in river and hatching *hapas*. Initially the fungus attacks the dead eggs and thereafter spreads on to the viable ones resulting in their partial to complete spoilage. The presence of *Saprolegnia* sp. at all the four sampling stations during spring and summer seasons is an indication that the fungi may be invading all stages, from spawn to adult fishes of the river. *Saprolegnia* and species as *Aspergillus* infect the fishes during transportation and storage too. This needs more detailed studies in second phase.

The presence of keratinophyallic fungi *Chrysosporium* and *Pseudogymnoascus* species on the banks of Ganga is due to the availability of significant quantity of keratinous material like human hair in the bathing ghats and bones in cremation sites. Species of *Humicola* and *Penicillium* have also been isolated from the above mentioned sites. These fungi are initial colonizers of hairs, bones, etc. (de Vries, 1962). The keratinous medium may also help the growth of some dermatophytic fungi and cause diseases in humans and animals using the river water for different purposes.

It is interesting to note that by and large at high BOD values the number of fungi isolated decreased in different seasons at the four stations. However, the BOD level supporting higher number of fungi varies from season to season, but the trend remains the same. In a particular season of the year, a higher BOD value is less supportive than lower values of BOD of that season. Thus a lower BOD value of seasons of a year may be less supportive in that year and seasons but the same value may be on higher side in another season of the year.

There appears to be to some extent a positive correlation between temperature and the number of fungi isolated. There was a linear relationship between temperature of the Ganga river water and number of fungi present. It was observed that the number of fungi increased with an increase in the temperature of river water. At 25° C or above, the number of fungi isolated decreased. A temperature of 18° C appears to be highly supportive for fungi as the number of fungi is highest where the temperature prevails. Similarly, temperatures lower than 18°C reduce the number of fungi. The *p*H of water does not appear to have any influence on the mycoflora. The number of fungi also showed linear relationship with the BOD (mg/l) of river water. However, the latter decreased with an increase in the number of fungi. It cannot be said with certainty that only one factor is responsible for influencing the mycoflora. There is an interaction of BOD/temperature, substrate and some other factor (s) in determining the mycoflora of the river bank at these locations.

Macrophytes : Forty one different algal genera have been isolated from the river Ganga from four different stations (between monsoon season 1987 to spring season 1990). Of these 5 belonged to Cyanophyta, 14 to Bacillariophyta, 21 to Chlorophyta and 1 to Euglenophyta. Some of the algae isolated e.g. *Oscillatoria, Phormidium, Anacystis, Melosira, Navicula, Nitzchia, Synedra, Ankistrodesmus, Closterium, Scendesmus* and *Euglena* can be used as biological pollution indicators of water (Palmer, 1980).

Palmer has given an algal genus pollution index from 1 to 5. According to this index *Euglena* and *Oscillatoria* are the highest, i.e. 5, and index of *Scendesmus* is 4.

The above three genera have been isolated from all the four stations of the river Ganga but their presence is moderately high at Kannauj. Thus we believe that the water at Kannauj is comparatively more polluted than the other three stations, i.e. Narora, Katchla and Fatehgarh. The same trend is indicated by other parameters like BOD and Primary Productivity.

Shore Flora : In all, forty species of plants belonging to nineteen families were encountered during the survey from 1989-1990. Species of *Saccharum*, *Scirpus*, *Typha*, *Tamarix*, *Ammamia*, *Rumex*, *Pomea*, *Polygonus* and *Eclipta* were amphibious in habit while species of *Vallisneria*, *Nechamandra* and *Hydrilla* preferred aquatic habitat. The remaining were found to prefer mesophyte habitat.

Not all the species of angiosperms were found round the year. But the number of plant species was more during winter and rainy seasons than in dry summer.

Species of *Saccharum* (*bengalense* and *spontaneum*) and *Cynodon dactylon* growing on the banks from Narora to Kannauj are good soil binders.

Ipomea fistulosa and *Tamarix dioica* which are shrubs are present at all four stations. They are soil binders as well as help in keeping the course of the river intact. Some shrubs and trees which can be planted near the bank of the river Ganga to check erosion and to prevent the river from changing its course, especially at Narora, Kannauj and Fatehgarh are *Adhatoda vasica*, *Prosopis spicigera*, *Butea monosperma*, *Acacia nilotica* and *Zizyphus*.

Phytoplankton : Phytoplankton belonging to five taxonomic groups namely blue green algae (Myxophyceae), desmids (Desmidiaceae), diatoms (Bacillarioplayceae), flagellate algae (Eugleno- phyceae) and the green algae (Chlorophyceae) were identified in the river water.

In all 75 genera were identified at different stations during the period of investigations i.e. from postmonsoon 1987 to spring 1990. Out of these 13 genera each belonged to blue green algae and desmids, 21 to diatoms, 2 to flagellate algae and 26 belonged to green algae. Diatoms and green algae were the chief contributors to phytoplankton at all the stations. *Closterium* was found to dominate numerically. The other genera which have, at times, been found among the abundant genera are *Navicula*, *Actinastrum*, *Protococcus*, *Asterionellas*, *Microspora* and *Melosira* etc.

With respect to the total number of individuals and the contributory genera, an overall dominance has been demonstrated by the diatoms and green algae at different stations in various seasonal samples. Next to these groups, in abundance were desmids and the blue green algae whereas the flagellate algae were rare or altogether absent in many seasonal samples at all the stations.

The overall maximum value of phytoplankton was recorded at Kannauj during winter 1988 while it was minimum during postmonsoon 1987 at the same station. The maximum total number of genera encountered in a sample was observed at Kannauj during postmonsoon 1989 and the minimum was noted at Katchla during postmonsoon 1987.

Odum's Index of Diversity as Biological Indicator of Pollution : The diversity index in the phytoplankton genera was determined as biological index of pollution. The mean value of the O.I. over the seasons was highest at Katchla showing the lowest degree of pollution at this station followed by Narora and Fatehgarh, respectively. Kannauj water showed the lowest value of an overall average representing the most polluted among the four stations of river stretch under study.

Palmer's Algal Genus Index : An overall AGI value of sample was taken as sum total of rates scored by each tolerant genus encountered in a seasonal sample and the water quality was reckoned as A, B, C etc. according to the AGI 0,1,2 etc. The status of water quality was found to be of A grade during winter '87, postmonsoon '89, winter '89 and spring '90 seasons at all the stations whereas it was B at all the stations during postmonsoon '88 and in winter '88, the quality degraded to C at Fatehgarh and D at Kannauj. During spring and summer '89 the quality of water was A at all the stations except Kannauj where the Palmer AGI was raised deteriorating the water quality to E grade in spring and C in summer. During postmonsoon '87 Narora and Kannauj showed lowest Palmer's AGI value with A quality but at Katchla water quality was B and at Fatehgarh it was D. The water quality improved downstream with B quality at Narora and Katchla and A at Fatehgarh and Kannauj. The mean values of total AGI over all the seasons at different stations were used to reckon water quality. The values increased as one moved downstream. Narora and Katchla were found to be less polluted than the stations of Fatehgarh and Kannauj. Kannauj water recorded the highest value of mean AGI. The order of the degree of pollution on the basis of Palmer's AGI is also confirmed by the values of Odum's Index diversity (O.I.) in phytoplankton. The O.I was highest at Katchla on an average as well as during most of the seasons and lowest at Kannauj.

It is evident from these observations again that the highest degree of pollution was recorded at Kannauj while it was least at Katchla. The Palmer's algal genus index increases with pollution while the phytoplankton diversity tends to decline with pollution.

Zooplankton : Stationwise and seasonwise, qualitative and quantitative analyses of zooplankton of the entire study period (1987-90) revealed, that the major zooplankton groups viz. copepoda, cladocera and rotifera varied highly in absolute number. The rotifers exceeded in number than copepoda and cladocerans. Rotifer population was dominated by the genera *Brachionus* and *Keratella*. The copepoda is constituted by *Diaptomus* sp., *Mesocyclops hyalimus* and *M. leuckarat*, whereas the cladocera was represented by *Bosmina* sp., *Ceriodaphnia* sp., *Diaphanosoma* sp., *Leydizia* sp., *Moina* sp., and *Simocephalus* sp.

The mean value of Odum's diversity index between postmonsoon 1987 to spring 1990 was high at Katchla followed by Narora, Fatehgarh and Kannauj. High index value indicate more species diversity and better quality of water and less value is meant for fewer number of species and the polluted nature of the water.

Benthic and Shore Line Fauna : The benthic and shore line fauna include mollusca, ostracoda, oligochaeta, insecta and nematoda.

Molluscs : Even though a number of species were encountered during the study period only a few among gastropods such as *Buthynia* sp., *Indoplanorbis* sp., *Subulina* sp., and *Vivipara bengalensis* were most remarkable among bivalves as far as their occurrence and abundance is concerned.

Ostracods : *Cypris* sp., and *Heterocypris* sp., were important species of ostracods, however, *Cypris* sp., was markedly absent in Fatehgarh.

Insects : *Chironomus* sp. *Culicoides* sp., and *Tendipes* sp. were most abundant than others. *Megistocera* sp., *Simulium* sp. and *Stenelemis* sp. were less abundant and rarely encountered.

Nematodes : Nematodes occurred most abundantly in all the seasons at all the four sampling stations.

Primary Production

The values of gross (GPP) and net primary production were generally higher at Kannauj followed by Fatehgarh, Narora and Katchla respectively in decreasing order. The overall maximum value of gross as well as net primary productivity was found at Kannauj during postmonsoon '89 whereas the minimum value of GPP was recorded at Fatehgarh during winter '87 and value of the NPP at the same station during winter '89 was recorded as overall minimum. All the stations showed the minimum value of GPP during winter '87. The highest value of GPP and NPP at Narora were recorded during Summer '89. NPP at Narora was least during winter '89. At Katchla maximum value of NPP was recorded in winter '87.

The maximum value of GPP and NPP were observed in postmonsoon 1989 at both Fatehgarh and Kannauj stations. No definite pattern was followed by the primary production values at these stations over different seasons.

Toxicity of Pesticides : Short-term static bioassays were conducted in the laboratory using different species and life stages to test the toxicity of various pesticides. Majority of these pesticides have also been detected in the stretch of the Ganga river water under study. The pesticides used were Aldrin, BHC, DDT, Thiodon and Malathion. Standard methods as recommended by APHA (1985) were used to determine the 96 hr LC50 of these pesticides for the experimental fishes.

The toxicity of different pesticides was tested on a few species of fresh water fishes found in Ganga. The 96 hr LC 50 value in mg/l is an index of the median lethal concentration for the species tested under an exposure of 4 days. The load of these pesticides has been detected in the river water in quantities quite below the LC 50 values for various fishes. The sublethal concentration present in the river water may prove physiologically harmful for fish in long term exposure. The organochlorine pesticides have their long term effect due to their non-degradation and residual effects. Bioaccumulation and biomagnification of these pesticides through food chains is quite deleterious to fishing resources as well as to the human populations making use of river water for various purposes.

Main Geographical Findings

Lying mostly in riverine Khadar belt along the Ganga, the region has good, fertile soils and is predominantly agricultural.

High Density of Population : Overall density of the districts comprising the study area is 400 – 800 persons per sq km. Population density in the sample villages is over 494 persons per sq km which is much higher than Indian population density (196 persons/sq km). Population is predominantly rural. Agricultural density is very high. Agriculture is highly intensive with high incidence of double cropping. Over 92% of the total cultivated area is irrigated. Rainfed agriculture is negligible.

Irrigation is not fully developed in villages in the immediate vicinity of the river, but away from the river it is well developed.

Economic basis is overwhelmingly agricultural. 72.4% of the total area is devoted to agriculture. 94.47% of the total population of sample villages is dependent on agriculture.

High Overall Irrigation Intensity : Over 425 kg per hectare of the area is under N.P.K. Nitrogen is the predominant fertilizer followed by phosphorus and potassium in that order.

Only 0.46 kg per hectare organochlorine is predominantly used accounting for over 97% of the total insecticides and pesticides used.

The level of agricultural mechanization is quite low in villages situated along the bank of the river Ganga (economic, religious and backwardness factors being responsible).

Nallahs and streams joining the Ganga on either banks drain into the Ganga river from both the sides, carry domestic, industrial and agricultural pollutants in large quantities to the Ganga.

Several water borne diseases such as cholera, diarrhoea, dysentery, kidney stones, malaria, goiter etc. have been found rampant in the sample villages.

Major Geological Findings

At this gradient the river is flowing at a low velocity and it has a very smooth flow. In this part river can carry dissolved, suspended and traction load. Suspended load includes, flaky minerals like mica and pieces of mica schist, fine and very fine sand, silt and clay. The load in traction includes medium and coarse sand.

Studies have shown that dissolved elements are present and in many parts precipitated lemonite, sederite and calcium carbonate in the form of *Kankar* have been found as nodules. In some parts of the river bed specially on the up-stream side of Sankara stagnant pools on the side of the river have green coloured water. This green colour is not due to any fungi or algae but it is due to dissolved elements. It is poisonous and fatal to cattle.

Other dissolved materials are the compounds oxalate, phosphate and fluorides. These cause kidney stones in both men and cattle. The incidence of kidney stones is so high that it is reported even in children below three years and cows and buffaloes. During the field survey it was found that stones incidence occurs in pocket and it was also found that the food habit of persons living in these pockets as well as outside the pockets was the same. Therefore, it is inferred that oxalate and phosphates may be concentrated in the soil in source areas and it goes in to the animal body through drinking water. Fluorosis is a common disease in some parts of Badaun district and it is caused by the absorption of dissolved fluorides. Sample load goes down the river in the form of clay, silt, very fine and fine sand grades.

It is possible due to low velocity at Narora barrage that in all the samples except those of Kannauj coarse sand is less than 1%. In Kannauj the increase in the coarse sand is possibly due to addition of sediments brought by Ram Ganga. Ram Ganga joins opposite Kannauj and the samples were collected from the downstream side of Ganga and the Ram Ganga confluence. In occasional samples the percentage of medium sand also increases. However, in Ramghat it is consistently high.

In most of the samples clay, silt and fine sand percentage is high. This material must be coming across the barrage as suspended load. In Katchla and Ramghat area in some pockets biotite, muscovite, mica and schist flakes were recorded. At Katchla it may be coming from Mahawa Nadi, which comes from the North and joins Ganga on the upstream side of Katchla. In Ramghat these flakes may be coming from suspended load.

In all the samples heavy minerals are less than 0.5%. This is surprising, as Ganga comes from igneous rocks bearing area and it should be bringing high percentage of heavy minerals. Possibly all the heavy minerals are held with the coarse sand on the upstream side of the barrage at Narora. A slight increase in the heavy mineral at Kannauj must be from Ram Ganga sediments. In samples near Narora, Ramghat and Kannauj animal bone pieces were found along with the fine sand.

This study has shown that a detailed study of the sediments on the upstream side of Ganga barrage, and along the north bank of the Ganga is very essential. It is only then that the cause for the absence of coarse sand can be found.

Conclusions

It would be evident from the above that the stretch of the Ganga between Narora and Kannauj is comparatively pollutant free as compared to other stretches of the river which receive industrial and urban sewage discharge in appreciable quantities. Except Neoli sugar-mill near Katchla, no other major industries are located in the area. The waste of the mill is not visibly discharged into the river. The open drains of the villages situated at the bank of the river, nallahs, agricultural run off and tributaries of the river in this region bringing in pollution loads appear to be the major cause of deterioration of the water quality in the river reach. The water quality deteriorates from "B" to "D" from Narora to Kannauj d/s. The heavy metal load is within the prescribed tolerance limits for drinking water except Hg, Fe and Pb. The high values of these heavy metals are probably due to adsorption of metals on the suspended particles in water and needs further probe. The microbiological quality of the water is either "C" or "D". In this region faecal streptococci appears to be a true microbiological indicator of pollution. Although the river water in this stretch appears to be cleaner in terms of pesticides and heavy metal loads, the detection of multiple drug/antibiotics resistant Coliforms, R-plasmid harbouring Coliforms and mutagens are important findings that require more systematic studies in the second phases. *Euglena, Oscillatoria, Phormidium, Anacystis, Melosira, Navicula, Nitzshia, Synedra, Ankistrodesmus, Closterium* and *Scenedesmus* appear to be biological indicators of pollution in the river reach. Suggestion has been made to plant certain kinds of plants on the river banks to check erosion and prevent the river from changing its course. The presence of cellulose-degrading and keratinophilic fungi needs further studies for its role in biomass production. The findings of the *Geography Group* and *Geology Group* are quite interesting. The suggestions made by these groups call for further action in the second phase.

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21

River Ganga in the Stretch Between Kalakankar (Pratapgarh) and Phaphamau (Allahabad) : A Comprehensive Study

A.K. SINHA*

River Ganga – popularly called 'Ma Gange' in this region has been the subject of study by the author and his co-workers during the last few years (Sinha, 1988). In an earlier study between Shuklaganj (Unnao) and Kalakankar (Pratapgarh), Chemical, Botanical, Microbiological and Zoological studies were carried out at ten sampling sites. This showed that although the pollution of the river in this stretch is mainly due to the discharge of effluents/waste waters by the tanneries and urban sewage, the human interference and activities like bathing especially mass-bathing at important Hindu festivals, cremation and dumping of dead bodies and carcases and use of pesticides and insecticides are also responsible for the deterioration of water quality of the River. Subsequently, these studies were extended to this stretch of the river between Kalakankar (Pratapgarh) and Phaphamau (Allahabad) and our observations are presented in the following pages.

The stretch of the river included under the present studies lies between 80° 33′ N and 26° 43′ E longitude and 24° 47′ N and 26° 15′ N latitude covering the district of Pratapgarh on Northern side and the District of Allahabad on the Southern Side (Figure 21.1).

Samples were collected once a month from left bank, midstream and right bank of the river at Phaphamau, Shringverpur, Haudeshwar Nath and Kare-Manikpur. Standard methods were used in the analysis of water and sediments and in the studies on flora and fauna.

1.0 CHEMICAL STUDIES

(A) Water

(A.1) *Physico-chemical characteristics* : The river water was monitored for certain physico-chemical parameters (temperature, *p*H, conductivity, turbidity, total solids, total dissolved solids, total suspended solids, dissolved oxygen, bio-chemical oxygen demand, chemical oxygen demand, alkalinity, hardness, fluorides, phosphates, nitrates, sulphates, chloride and total nitrogen) for two years during September 1987 – August 1988 and July 1989 to June 1990. Range of these parameters during the period mentioned has been shown in Table 21.1. It may be observed from the table that the river water is polluted at the sites selected. It was also noted that during rainy season the water is less polluted while during summers the water is grossly polluted. Although there is no apparent source of pollution of the river in this stretch, except a few sewage drains at Phaphamau, it appears that the pollutants discharged in the river stretch between Shuklaganj (Unnao) and Kalakankar (Pratapgarh) travel down and make the river water unfit in this stretch of the river.

(A.2) *Heavy metal concentration* : The concentration of eleven heavy metals (Ca, Fe, Mg, Mn, Hg, Pb, Cu, Cr, Ni, Zn and Cd) was estimated in the river water samples of the selected sites every month during January, 1988 and June 1988 using the procedure described in APHA (1980) with the help of atomic absorption spectro-photometer.

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TABLE 21.1

Range of Physico-chemical Characteristics of the Ganga Water between Phaphamau (Western side) and Kare-Manikpur during September 1987 to August 1988 and July 1989 to June 1990

Parameter	Period	Phaphamau Bridge (Western Side)			Phaphamau Bridge (Eastern Side)		
		Left	Mid	Right	Left	Mid	Right
01 A.T.° C	9/87–8/88	20.0-31.0	20.0-33.0	20.0-34.0	19.0-32.0	21.0-34.0	21.0-35.0
	7/89–6/90	22.0-34.0	22.0-34.0	23.0-34.0	25.5-35.0	22.0-34.0	22.0-34.0
02 W.T.° C	9/87–8/88	19.0-30.0	19.0-29.0	19.0-35.0	19.0-30.0	19.0-30.0	19.0-33.0
	7/89–6/90	19.0-32.0	19.5-31.0	21.0-32.0	20.0-32.0	19.5-31.0	19.0-032
03 *p*H	9/87–8/88	7.51-8.84	0-61-8.72	7.62-8.72	7.56-8.76	7.92-8.76	7.66-8.95
	7/89–6/90	7.18-8.48	7.23-8.58	7.72-8.78	7.85-8.35	7.13-8.48	7.03-8.48
04 Turb. (N.T.U.)	9/87–8/88	6.0-27.09	8.2-28.1	8.9-28.3	6.0-26.0	6.0-90.0	6.0-27.2
	7/89–6/90	–	–	–	–	–	–
05 Conductivity mmhos/cm	9/87–8/88	0.20-0.58	0.20-0.58	0.20-0.58	80.19-0.59	0.19-0.57	0.15-0.59
	7/89–6/90	0.24-0.45	0.25-0.44	0.26-0.47	0.26-0.50	0.25-0.51	0.28-0.53
06 Dissolved Oxygen (DO)	9/87–8/88	5.3-11.1	5.3-13.4	5.5-11.3	3.2-12.0	5.7-12.6	5.3-11.8
	7/89–6/90	5.7-9.8	5.9-11.5	5.8-10.1	5.7-10.5	5.8-11.2	5.4-9.80
07 Biochemical Oxygen Demand (BOD)	9/87–8/88	1.2-4.8	1.4-8.7	6.0-2.1	1.2-6.7	1.6-7.3	1.7-7.9
	7/89–6/90	4.5-6.5	4.3-6.2	4.8-6.7	5.0-6.7	5.5-6.3	5.1-6.9
08 Chemical Oxygen Demand (COD)	9/87–8/88	10.0-42.0	8.0-40.2	8.0-24.0	8.0-48.0	8.0-52.0	8.0-41.2
	7/89–6/90	34.2-74.2	32.2-76.2	30.5-75.5	35.5-78.5	32.2-85.8	30.5-75.1
09 Fluoride	9/87–8/88	0.21-1.62	0.23-1.62	0.20-1.20	0.26-1.26	0.55-1.24	0.30-1.25
	7/89–6/90	0.28-0.76	0.35-0.88	0.58-0.70	0.21-0.78	0.35-0.85	0.38-0.90
10 Phosphate	9/87–8/88	0.31-0.98	0.35-1.54	0.21-1.32	0.224-1.77	0.72-1.45	0.25-1.32
	7/89–6/90	0.23-1.80	0.25-2.10	0.25-2.38	0.23-2.10	0.24-1.98	0.25-2.35

(Contd.)

TABLE 21.1 – *Contd.*

Range of Physico-chemical Characteristics of the Ganga Water between Phaphamau (Western side) and Kare-Manikpur during September 1987 to August 1988 and July 1989 to June 1990

Shringverpur			Haudeshwar Nath			Kare-Manikpur		
Left	Mid	Right	Left	Mid	Right	Left	Mid	Right
25.0-36.0	24.0-35.0	25.0-36.0	14.0-32.0	14.0-34.0	20.0-32.0	22.0-32.0	22.0-38.0	22.0-33.0
25.0-35.0	23.0-34.0	24.0-34.0	18.0-31.0	17.0-31.0	19.0-31.0	23.0-23.0	23.0-23.0	23.0-23.0
20.0-32.0	19.0-31.0	19.0-31.0	19.0-30.0	18.0-30.0	19.0-3.0	19.0-30.0	19.0-35	19.0-31.0
20.5-32.0	20.0-31.0	20.0-32.0	18.0-31.0	17.0-31.0	19.0-31.0	23.0-23	23.0-23.0	23.0-23.0
7.11-8.95	7.11-8.92	8.04-8.91	7.25-9.03	7.89-9.12	7.94-8.98	7.45-9.12	7.26-9.12	7.89-9.06
7.25-8.48	7.31-8.48	7.28-8.45	8.37-8.58	8.26-8.86	7.38-8.76	8.21-8.42	8.31-8.51	8.32-8.52
4.4-27.8	5.0-10.6	6.0-12.6	5.2-7.2	7.0-6.0	7.0-21.8	4.8-26	9.0-28.1	4.0-28.8
—	—	—	—	—	—	—	—	—
0.16-0.58	0.31-0.57	0.30-0.56	0.20-0.55	0.27-0.54	0.26-0.59	0.30-0.59	0.20-0.60	0.20–0.60
0.18-0.48	0.21-0.47	0.22-0.41	0.23–0.51	0.22–0.53	0.21–0.53	0.31–0.41	0.32–0.44	0.32–0.45
5.3-11.5	5.9-11.5	6.1-12.0	6.4-13.9	5.19-11.8	6.3-12.0	5.7-14.2	6.0-13.4	6.0-13.4
6.21-11.1	6.0-12.2	5.8-10.2	7.8-9.1	5.7-9.5	5.2-8.3	3.1-9.2	4.6-9.9	4.0-9.1
2.2-6.2	2.6-6.2	1.6-5.7	1.8-7.4	1.2-4.9	2.4-6.3	2.1-8.3	1.8-7.3	2.0-5.1
4.0-5.5	4.5-5.2	4.5-5.0	4.9-5.6	4.6-5.4	4.0-5.5	5.1-6.7	5.2-6.2	4.9-6.6
8.0-30.1	12.5-35.2	12.0-48.0	10.0-38.5	8.0-45.5	8.0-40.1	12.1-52.5	8.6-53.8	8.0-50.2
40.2-60.2	40.0-65.8	45.0-62.2	67.8-78.2	70.5-80.2	65.6-85.5	69.8-70.5	65.1-75.0	68.2-80.5
0.23-1.45	0.63-1.12	0.33-0.82	0.27-1.22	0.27-1.21	0.25-1.22	0.22-1.12	0.21-1.20	0.25-0.95
0.16-0.80	0.17-0.79	0.12-0.78	0.04-0.81	0.23-0.98	0.35-0.98	0.38-0.48	0.35-0.78	0.39-0.88
0.23-1.20	0.60-1.80	0.68-1.10	0.24-1.95	0.73-1.31	0.94-2.16	0.35-1.26	0.36-1.62	0.35-2.88
0.18-2.80	0.23-1.90	0.25-0.98	0.78-1.25	0.98-1.31	0.58-1.58	0.48-1.18	0.68-1.38	0.58-0.89

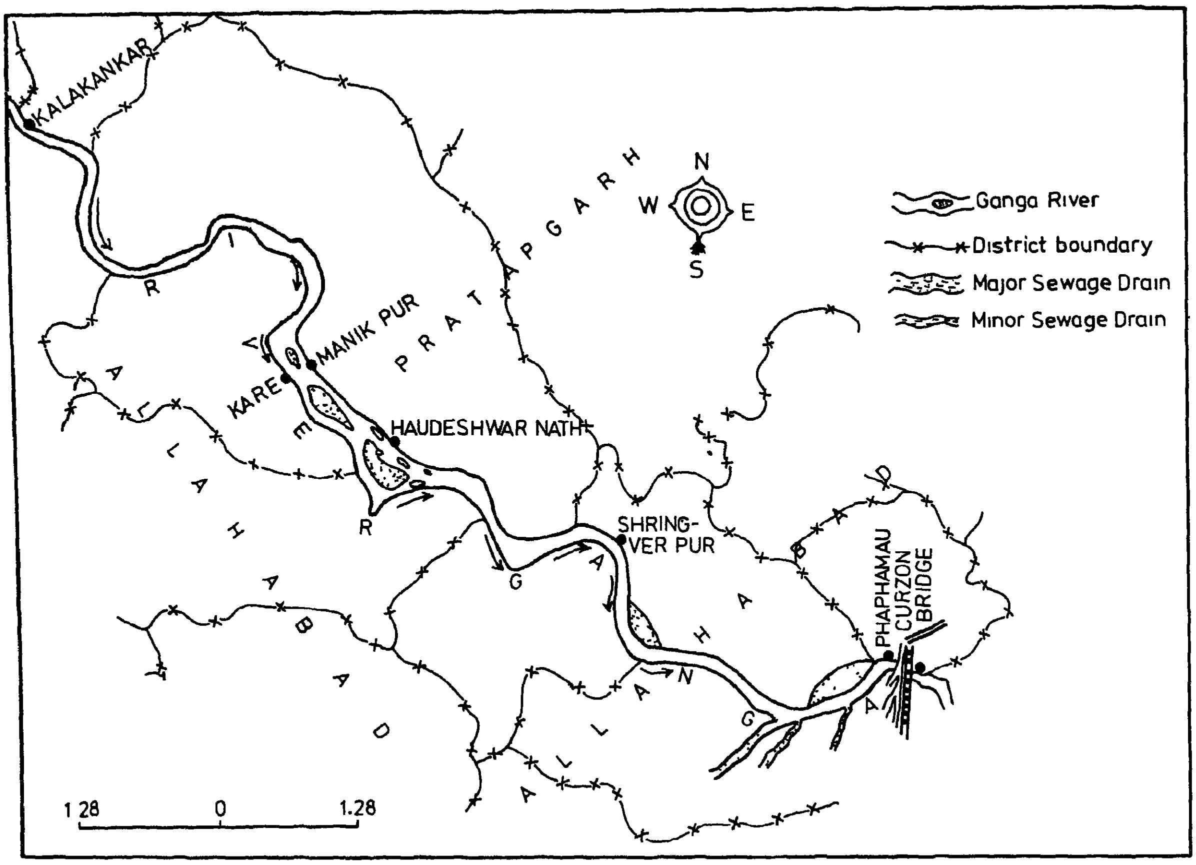

Figure 21.1 : Map of Stretch of the River Ganga between Kalakankar and Phaphamau

The range of concentration (in ppm) of the metals studied was : Ca : 10.012 – 32.58; Mg : 0.18 – 0.413; Cu : 0.01 - 0.16; Zn : 0.002 - 0.82; Ni : 0.12– 1.04; Cd : 0.0 - 0.718; Cr : 0.03 - 0.62; Pb : 0.08 - 0.36; Mn : 0.006 - 0.934; Fe : 0.17 – 6.7. Mercury was not detected at any of the selected sites. The concentrations of these metals studied in the river water between Shuklaganj (Unnao) and Kalakankar (Pratapgarh) was also observed to be exceptionally high, probably because of the discharge of tannery waste, urban sewage and agricultural run off. During the present studies, the concentration of metals was higher at Phaphamau than at the remaining sites, which may be attributed to the discharge of city sewage/waste and opening of new nullahs at the site.

(A.3) *Pesticide residues* : The presence and concentration of the widely used pesticides BHC, DDT, Endosulfan, Malathion, Methylparathion, Ethion and Dimethilate were studied in January, 1988 and June, 1988. Results revealed high concentrations of BHC, DDT and Endosulfan at all the selected sites. Incidentally these are the pesticides that are commonly used in this area. It appears that these pesticides did find their way into the river water through agricultural run off.

(A.4) *The Water Quality Index* : (WQI) of the river was calculated using the method described by Tiwari, *et al.*, (1985). WQI of the selected sites have been shown in Table 21.2.

TABLE 21.2

WQI of the Ganga Water between Phaphamau (Allahabad) and Kare-Manikpur (Pratapgarh)

Station	August	December	April
Phaphamau (Eastern Side)	77.90	84.98	86.30
Phaphamau (Western Side)	78.31	95.719	117.89
Shringverpur	83.85	75.27	84.18
Haudeshwar Nath		110.05	83.25
Kare-Manikpur	65.49	81.69	89.33

For the present studies, it has been assumed that water having WQI 50 shall be treated as fit for human consumption. WQI 80 will be moderately polluted, 80 will be excessively polluted and 100 will be considered as severely polluted. On the basis of our observations presented in Table 21.2, it was noted that water of Phaphamau is severely polluted while at remaining sites the water was observed to be moderately to excessively polluted as exhibited by WQI values. But at the Haudeshwar Nath in the month of December the water is severely polluted. It has also been observed that the values of WQI generally decreased in August because in this month the river water increased due to rains and WQI values increased during December and April, when the amount of river water decreased. Tiwari and Mishra (1985), who studied the water quality of river Ganga at Garhmukteshwar and calculated the WQI, reported that the water is severely polluted at Garhmukteshwar. Sinha (1988) studied the water quality Index between Shuklaganj (Unnao) and Kalakankar (Pratapgarh) and concluded that the higher values of WQI at Shuklaganj, Jajmau and Jajmau Pumping Station – the seat of industrial activity, might be due to the discharges of effluents and wastes into the river and due to human activities. In the present studies the WQI at Haudeshwar Nath were observed to be highest during April and December respectively. At Phaphamau the river receives city sewage and other wastes from the upstream (Rasoolabad) and opening of the new nullahs, while at Haudeshwar Nath mass bathing and cremation takes place regularly. The increase in WQI at these places might be due to these factors. At the remaining sites the deterioration in water quality as evidenced by WQI may be due to agricultural run-off, washing, bathing, cremation and dumping of human and animal dead bodies, which is a common practice in this stretch of the river.

(B) Sediments

River sediments constitute the abiotic component of an aquatic ecosystem. The word sediment signifies solid material that has settled down from suspension in liquids. Here the word sediment has been used for the benthic soil of the river. Pollutants discharged into the river ultimately settle down in the sediments causing change in their physico-chemical characteristic. With a view to study the effect of pollutants discharged/transported on the sediments, the present studies were conducted.

(B.1) *Physico-chemical characteristics* : Physico-chemical characteristics of the river Ganga sediments at the selected sites were studied during January 1988 to December 1988 and during July, 1989 to June, 1990. The parameters studied were: *p*H, conductivity, chlorides, hardness, total alkalinity, SO_4, PO_4, NO_3 and total nitrogen. While the values of most of parameters were not observed to change appreciably, noticeable change in the values of certain parameters was observed. This may be due to changes in the composition of the pollutants discharged/transported into the system.

During a comprehensive study of river Ganga between Shuklaganj and Kalakankar, physico-chemical characteristics of river Ganga sediments in this stretch of the river was also studied (Sinha, 1988). A comparison of the data on sediments between Shuklaganj and Kalakankar and those between Kalakankar and Phaphamau revealed that the values in the later stretch were lower than the values in the former stretch. On this basis, it may be concluded that the pollutants discharged into the river get washed away along with the water currents and do not completely settle down into the sediments at the place of their discharge. This may probably be the reason for the higher values of physico - chemical parameters in the sediments of the river at Shuklaganj (Unnao) than those at Phaphamau (Allahabad).

(B.2) *Heavy metal concentrations* : The range of concentrations of heavy metals studied were : Ca : 301.5 – 9778.3; Mg : 1050.2 – 17244.0; Cu : 3.9 – 42.2; Zn : 2.15 – 79.79; Ni : 30.13 – 115.37; Cd : 1.99 – 16.28; Cr : 7.58 – 91.66; Pb : 3.8 – 49.83; Mn : 13.25 – 272.72; Fe : 305.7 – 2916.22; Hg : 0.936 – 3.28. It was observed that the concentration of these metals was higher at Phaphamau (Allahabad) than at the remaining sites.

It may be noted that the sources of discharge of heavy metals into the river Ganga between Shuklaganj (Unnao) and Phaphamau (Allahabad) are located at Kanpur where effluents of the tanneries contain the heavy metals studied. A comparison of the data of earlier studies (Sinha, 1988) with those of the present studies revealed that the concentrations of heavy metals have decreased as the river flows downwards from Shuklaganj to Phaphamau.

It appears from these observations that the river Ganga has carried the heavy metals from the point of discharge into the river and the biota of the river has not been able to degrade/decrease the heavy metals studied. Metals are also released in the sediments through biochemical cycling (Hamilton –

TABLE 21.3

Pesticide Residue in the River Ganga Sediments between Kare-Manikpur and Phaphamau during April and June, 1988

(mg/gm)		Total BHC	Total DDT	Aldrin	Endo-Sulfan	Malathion	Ethion	Methyl Parathion
Phaphamau								
April	L	1.8990	0.3509	0.3876	4.8077	0.0011	ND	ND
	M	11.6490	5.4432	27.9070	0.8010	0.0536	0.0037	ND
	R	39.2173	6.8270	8.1395	5.1280	0.0271	0.0011	ND
June	L	216.1778	1.3624	12.2865	0.9174	0.0625	0.0029	ND
	M	20.9685	9.2557	5.2127	8.1350	0.0521	0.0019	ND
	R	140.2568	2.6057	1.9379	3.5100	0.0431	0.0013	ND
Shringverpur								
April	L	39.7733	25.5431	0.7752	8.0128	0.0281	0.0019	ND
	M	–	–	–	–	–	–	–
	R	53.9893	38.7266	2.3215	5.2183	0.0321	0.0012	ND
June	L	60.9493	32.6812	1.4205	4.4693	0.0586	0.0028	ND
	M	–	–	–	–	–	–	–
	R	103.7818	6.6510	0.4806	0.3205	0.0225	0.0017	ND
Haudeshwar Nath								
April	L	94.0074	7.4596	2.1318	0.4808	0.0372	0.0009	ND
	M	132.9220	0.5040	0.3880	1.6036	29.8000	ND	ND
	R	37.5000	2.8394	11.6279	1.6028	0.0254	0.0024	ND
June	L	69.9232	34.5301	0.4587	1.5267	0.0339	0.0059	0.0015
	M	42.8821	17.8498	0.5187	0.8917	0.0510	0.0031	0.0015
	R	74.5359	19.2550	0.6420	2.5112	0.0358	0.0025	ND
Kare-Manikpur								
April	L	32.7413	1.9517	13.7615	ND	0.0372	ND	ND
	M	1.7600	1.4514	0.0460	0.3205	0.0004	ND	ND
	R	34.4510	2.4329	15.212	5.3410	0.0032	ND	ND
June	L	88.5635	37.5095	3.6697	0.7634	0.0545	0.0029	0.0015
	M	34.8677	4.6114	29.3576	2.290	0.1131	ND	ND
	R	86.3215	25.0927	45.5213	1.3839	0.0395	0.0310	0.0025

– = Samples not available
ND = Not detected

Taylor *et al.*, 1984) and turbulence (Everard and Denny, 1985). In the light of these, the very high concentration of metals in sediments as compared to river water may be due to the fact that at alkaline *p*H, the metals present in water probably get hydrolysed and then deposited in the river bed, the sediments (Mathur *et al.*, 1987).

(B.3) *Pesticide Residues* : The concentration of total BHC, total DDT, Aldrin, Endosulfan, Malathion, Ethion and Methyl Parathion was estimated in sediment samples of selected sites in April, 1988 and June, 1988.

2 gms. sediment samples were extracted with the help of Soxhlet using 100 ml. n-hexane as solvent. The solvent was then pooled out from the apparatus and evaporated to about 1 ml. after which the residue was then made upto 5 ml. with n-hexane. Pesticide concentration was estimated on GLC and calculated using the formula of Singh *et al.*, (1987). The concentration of pesticides have been shown in Table 21.3.

Soil (sediments) has been regarded as the largest reservoir of all the non-biodegradable pesticides and act as a constant source of pesticide contamination in various water bodies and their sediments via run off water and soil erosion (Edward, 1973). The biological activities of different animals also play an important role in building up the residues of non-biodegradable pesticides at various levels of food chain. Higher values of DDT and BHC in river water and sediments may probably be attributed to these activities (Khapalia, *et al.* 1988). The high values of BHC isomers in water and sediment samples observed in the present study may be due to the bio-accumulating tendency, non-biodegradability and partition co-efficient (Fitzhugh, *et al.*, 1950).

(C) Effect of River Water and River Sediments

Root and shoot lengths of wheat (*Triticum aestivum*, Barley (*Hordeum vulgare*), Gram (*Cicer anetinum*) and Lentil (*Lens culinaris*) collected from Phaphamau and Kare-Manikpur on seed germination was studied in view of the fact that river water is generally used as an irrigant in this area. Observations of the present studies revealed that the river water of the selected sites increased the percentage germination while the sediments reduced the germination of the selected seeds. It was concluded from these observations that while the river water augmented the process of germination and early growth of the selected seeds the river sediments is generally detrimental to the process. This may be because of the fact that sediments contained some toxic materials which affected the process of germination and early development.

2.0 BOTANICAL STUDIES

(A) Survey, Collection and Identification of Flora

Ganga water is getting polluted due to intense human activities and infusion of foreign materials from the surroundings. These materials mainly comprise of decomposable organic mater of plants and animals, terrestrial washing, industrial, domestic, agricultural and other wastes. These wastes render the water unfit for either drinking or bathing. According to the circumstances, only such macrophytes are able to thrive and grow on the river bank and or in water as are able to adapt themselves to the changing of soil and water while the highly sensitive ones are being deteriorated or have disappeared.

Realising the significance of this selective sensitivity, a summary of the plants collected and identified between Kalakankar (Pratapgarh) and Phaphamau (Allahabad) is being presented here.

During the course of these studies a total of 99 plants belonging to 40 families including two pteridophytes (*Azolla* sp. and *Marselia quadrifida*) were collected. A few plants were observed to be restricted to a particular site as they were collected from that site only e.g. *Spergula arvensis, Coccinia cordifolia, Momordica dioiica, Ammania baccifera, Alhagi pseudalhagi, Vicia hirsuta, Vicia sativa* at Phaphamau, *Indigofera linifolia* at Kare-Manikpur, *Saccharum spontaneum* at Haudeshwar Nath, *Portulaca oleracea* and *Lindenbergia indica* at Shringverpur.

Seasonal variation studies of the collected plants were also made. It was concluded from the observations that maximum number of plants at each of the selected sites were collected in winters while minimum number of plants were collected in rainy and summer seasons. This is probably because of the fact that in this season new land emerges which permits various types of plants to grow and develop. In rainy and post-monsoon season, minimum number of plants have been collected because of the fact that river banks get submerged due to floods and the plants do not get space to grow. It was also observed that the plants which appear in winters die and decay during summers and reappear after the post-monsoon season.

TABLE 21.4

Number of Aquatic Fungi in one ml of the Ganga Water between Kare-manikpur and Phaphamau

Station	Site	September	October	November	December	January	February	March	April	May	June	July
Phaphamau	Left	9	10	13	14	13	12	9	8	A	A	8
	Mid	6	8	8	10	10	11	5	5	A	A	5
	Right	10	11	12	13	12	12	8	6	A	A	7
Shringverpur	Left	10	13	14	16	14	14	12	10	A	A	7
	Mid	8	9	10	14	12	12	10	8	A	A	5
	Right	11	14	15	18	16	14	10	9	A	A	8
Haudeshwar Nath	Left	10	12	15	18	15	15	13	9	4	4	8
	Mid	6	8	10	11	11	10	8	6	A	A	4
	Right	11	10	16	20	16	17	12	10	3	3	9
Kare-Manikpur	Left	9	8	12	12	12	10	8	8	A	A	3
	Mid	4	5	6	8	7	6	4	2	A	A	1
	Right	7	9	10	13	11	11	8	6	A	A	5

A = Absent.

TABLE 21.5

Number of Extra Aquatic Fungi in one ml of the Ganga Water between Kare-manikpur and Phaphamau

Station	Site	September	October	November	December	January	February	March	April	May	June	July
Phaphamau	Left	700	1200	1600	2400	1900	1500	1700	1300	1100	1000	600
	Mid	500	600	800	1500	1300	1100	900	800	800	600	500
	Right	800	1400	1800	2500	2000	1600	1800	1500	1200	1100	800
Shringverpur	Left	900	1100	1500	2100	1800	1500	1500	1200	1200	1300	900
	Mid	600	500	1000	1400	1200	1000	1000	800	800	800	600
	Right	800	1000	1300	1800	1700	1500	1200	1100	1100	800	400
Haudeshwar Nath	Left	800	1000	1100	2200	1700	1300	1400	1100	1200	1100	600
	Mid	600	800	800	1200	1200	1000	1000	900	800	800	300
	Right	900	1200	1400	2300	1900	1500	1500	1400	1300	1200	800
Kare-Manikpur	Left	800	900	1200	2400	1700	1600	1400	1100	1100	1000	700
	Mid	700	800	800	1800	1400	1100	1300	1000	800	700	500
	Right	900	1100	1400	2600	1800	1800	1500	1200	1200	900	800

lankton Density

anktons have been regarded as the chief oducers of natural aquatic ecosystems. y have been reported to be affected by the e water (Bilgrami, 1979, 1985). In recent s on phytoplankton density have been used n the quality of their environment. the phytoplankton density was estimated tember, 1987 and August, 1988 and again ugust, 1989 and April, 1990. It was from the results that maximum on density was recorded from r and minimum density from Phaphamau. planktons have been regarded as the ducers of the aquatic ecosystems, it may that the sites having higher phytoplankton be having higher productivity and those r phytoplankton density may be having ctivity.

riological Quality

ge of MPN/100ml values of total coliform rved in these studies at the selected sites × 10^3 and 24 × 10^5, that of Faecal tween 5 × 10^2 and 24 × 10^6 and that of ptococci between 7 × 10^2 and 11 × 10^5. um values were observed at Phaphamau estern side) and minimum values at ur midstream. The SPC values of aerobic ic bacteria ranged between 130 and 64186, m at Kare-manikpur midstream samples aximum at Phaphamau bridge (Western ever, the bacteriological population was those recommended by ISI (ISI 2296 : land surface waters to be used for drinking, recreational uses.

lora of River Water

lay an important role as decomposers in the equilibrium in an ecosystem. It is a fact that fungal population is affected by ecological conditions. The aquatic fungi usceptible to these changes in an aquatic The mycoflora (both aquatic and extra- s therefore, studied.

concluded from the present studies that ly extra aquatic fungi were maximum at and Kare-manikpur and the aquatic fungi num at Haudeshwarnath (Table 21.4 & litatively, of the extra aquatic fungi isolated fied, *Aspergillus* was present at all the selected sites. However *Achlya* spp., out of ten aquatic fungi isolated and identified showed preferences for comparatively purer sites. Similar observations have been reported by Cooke (1970), Tan (1984) and Sinha (1988).

3. ZOOLOGICAL STUDIES

3.1. Survey, Collection and Identification of Fauna

Systematic survey of the river at the selected sites was carried out during the period September, 1987 and June, 1990. As a result of regular survey and collection of samples from left bank, midstream and right bank of the river, one hundred seventy five animals were collected and identified. One hundred and five were invertebrates and the rest were vertebrates. Phylumwise distribution of the animals identified were : Protozoans – 18, rotifers – 16, platyhelminthes – 4, aschelminthes – 4, annelids – 7, crustaceans – 13, odonata – 4, ephemeropterans – 2, neuropterans – 2, hemipteran – 8, coleopterans – 8, trichopterans – 2, dipterans – 5, arachnid – 1, gastropods – 8, lammillibranchians – 3, fishes – 57, amphibian – 1, reptiles – 3, aves – 8 and mammal – 1.

Our observations revealed that during monsoons when the river was flooded the invertebrate fauna was poor at all the sites and in the winter the fauna was observed to increase gradually.

Presence in large number of bacteria eating protozoans like *Colpedium* sp., *Paramecium* sp. and *Vorticella* sp. have been regarded as an indication of the deteriorating water quality of river Ganga. Some pollution indicator species of rotifers have been collected during the course of these studies i.e. *Brachinous* sp., *Keratella* sp., and *Filinia* sp. These observations are in agreement with those of Bilgrami and Datta Munshi (1985). Prabhavathy and Sreenivasan (1977) emphasized that rotifers exist in high alkaline water. According to Sampath *et al.*, (1979) the rotifers occur mostly in polluted waters and can be used as bioindicators. Rotifers can tolerate low oxygen level in water. The present studies support these above mentioned observations.

Presence of bioindicators, Chironomous larvae and *Tubifex* sp. at every site indicates the effect of pollution. The maximum number of Chironomous larva was present at Phaphamau and Shringverpur. Chironomous larvae and *Tubifex* sp. have been reported to survive under very low oxygen tension. According to Mahadevan and Krishnaswamy (1984) the chironomid population of the sampling site was found to be directly proportional to the pollutional status of the site and may be used as a direct indicator

TABLE 21.6

Zooplankton Density of the Ganga River between Kare–Manikpur and Phaphamau from Sept. 1987 to July 1988 (Unit = No /Litre)

Name of Site	Bank	September	October	November	December	January	February	March	April	May	June	July
Kare-Manikpur	Left	ND	167	105	70	42	52	ND	134	273	280	28
	Mid	88	87	ND	ND	27	26	ND	78	103	100	17
	Right	286	140	108	154	68	57	ND	146	280	289	23
Haudeshwar Nath	Left	ND	124	70	84	36	50	ND	99	191	210	44
	Mid	ND	109	113	ND	26	ND	ND	40	150	113	ND
	Right	ND	123	154	ND	104	ND	ND	108	182	197	10
Shringverpur	Left	90	75	140	96	118	93	134	150	250	105	19
	Mid	ND	ND	66	36	83	36	115	101	97	82	ND
	Right	ND	ND	104	79	100	79	104	143	199	98	ND
Phaphamau	Left	41	137	206	160	198	149	139	180	297	120	ND
	Mid	ND	92	50	143	185	60	79	88	108	65	ND
	Right	25	106	190	154	189	135	111	160	235	112	11

ND = Not Done

TABLE 21.7

Zooplankton Density of the Ganga River between Kare–Manikpur and Phaphamau from Aug. 1989 to April 1990

Name of Site	Bank	August	October	December	February	April
Kare-Manikpur	Left	37	41	139	153	183
	Mid	17	21	67	37	93
	Right	47	37	132	137	179
Haudeshwar Nath	Left	32	50	109	72	130
	Mid	9	17	32	24	39
	Right	24	41	98	67	109
Shringverpur	Left	23	122	123	141	169
	Mid	12	41	79	52	102
	Right	30	102	118	108	163
Phaphamau	Left	15	127	114	159	193
	Mid	10	65	77	86	89
	Right	20	108	110	165	198

of pollution at various levels. Similar observations were made during the course of these studies.

Tarzwell (1956) and Coker (1985) reported that *Eristalis* sp. and *Tubifex* sp. occurred in strong sewage pollution and anoxic waters. According to Anthony *et al.,* (1979) the presence of cyclopoid, copepods and cladocerans are indicative of organic pollution. *Eristalis* sp. and *Limnophora* sp. occurred in raw waters at Phaphamau, thus suggesting that river Ganga is polluted at Phaphamau.

Presence of *Hydropshyche* larvae in large number at Karemanikpur, Shringverpur and Phaphamau may probably because these sites are used as cremation sites. Higler and Tolcump (1983) have reported *Hydropshyche* larvae as bioindicator. Higher concentration of lamillebranchs and turtles were also observed at cremation sites, because these genera are reported to feed on dead organic matter. Presence of large number of molluscs at right bank of Karemanikpur, Shringverpur and Phaphamau suggest that these sites are rich in organic pollution. High load of organic pollution at these sites may be due to the practice of throwing half burnt and unburnt dead bodies into the river Ganga and due to cremation practices.

Fish fauna appear to be quite poor in the river as is evident from low species diversity. The fish population depends upon the limnological conditions of the water. The increasing industrialization on the Gangetic belt has adversely affected the fish population probably due to unfavourable abiotic conditions.

Although fishes did not show any marked seasonal variation but generally during winters and post monsoon period *maximum* variety of fishes were collected. Their fry and fingerlings have also been collected. *Rana limnocharis* was collected in all the seasons. The tadpoles were also collected during monsoon and post-monsoon seasons. Reptiles were observed in all the seasons while *Natrix piscator* was collected only during summer at Phaphamau site.

Among eight bird species *Milvus migrano* was seen in all the seasons. Of the birds, large number of them were only winter visitors i.e. *Anserindicus, Egrelta alba modesta* and *Todoma ferruginea. Ardea cinerea* was a winter visitor but it was also observed during post-monsoon periods. *Platanista gangetica* the only mammal was collected mostly in monsoon and post-monsoon months.

3.2. Zooplankton Density of the Ganga River

Zooplankton density at selected sites was studied during the period between September, 1987 to July 1988 and again between August, 1989 to April, 1990 (Table 21.6 & 21.7). It would be clear from the data that zooplankton density was maximum in summer and minimum in rainy season. Our observations are in agreement with those of Bilgrami and Datta Munshi (1985) and Yousuf (1989).

Presence of maximum Zooplankton population in summer might be due to the presence of higher population of bacteria. Plankton depend on water quality, remains of dead and decaying vegetation as well as burnt and half burnt bodies. These result in increase of the organic matter and growth of the bacterial population which increase the zooplankton density. This may be the reason for higher zooplankton density at left and right banks and lower zooplankton density in the midstreams.

The lower density of zooplankton during rainy seasons may be due to the flood and fast currents of the river water. Zooplankton density was observed to be more at Phaphamau, Shringverpur and Kare-Manikpur in comparison to Haudeshwar Nath because of high load of organic pollution of these sites. According to Brinley (1967), bacteria-eating protozoans i.e. *Colpedium* sp., *Paramecium* sp., and *Vorticella* sp., indicate the increase of organic pollution. Our observations support those of Brinley (1967).

3.3. Density of Community of Zoobenthos

The zoobenthos density at the selected sites was studied and maximum and minimum densities were observed in March-April and July-August respectively. It was also revealed that the Phaphamau site showed the maximum concentration of benthos and Haudeshwar Nath showed their minimum concentration.

The Benthic fauna of river Ganga were represented by Annelids, Arthropods, Nematodes and Mollusca. Prominent benthos that were collected included : *Tubifex* sp., *Cyclops,* sp., *Daphnia* sp., Dragon fly Nymph, *Corixa* sp., *Plea palluta Chironomous* larvae, *Melanoides tuberculata, Melanoides* sp., *Vivipara bengalensis, Vivipara crassa, Anodonta* sp. and *Lamillidens marginalis.*

3.4. Morphometric Features and Population of Ichthyo Fauna

Studies on morphometric features and population of the collected fishes in relation to water quality and seasonal variation was made. No definite correlation could be made between the size of the fishes collected and the water quality but it appeared that those

TABLE 21.8

Blood Parameters of Five Species of Gangetic Fishes (Number of Fishes Analysed, n = 20)

Sl. No.	Name of Parameters	*Labeo calbasu*	*Mystus cavasius*	*Rita rita*	*Wallago attu*	*Mastacembelus armatus*
1.	Length (cm.)	26.5–29.0 (28.5)	14.4–14.8 (14.6)	15.6–20.0 (17.3)	11.9 –66.5 (44.7)	13.5 –20.5 (19.2)
2.	Total Erythrocyte Count (million/mm^3)	2.7–3.1 (3.0)	1.8–2.2 (2.0)	1.5–2.2 (1.8)	1.4–2.4 (1.8)	1.2–2.0 (1.5)
3.	Total Leucocyte Count (No. /mm^3)	16,000–16,700 (16,496)	14,500–15,600 (15,303)	24,450–38,700 (31,898)	26,000 –39 750 (32,428)	14,450 –25,100 (19,614)
4.	Haemoglobin Percentage (%)	7.0–13.9 (11.0)	7.9–17.1 (12.6)	8.9–15.3 (11.9)	7.2–15.2 (11.9)	8.2–16.3 (13.0)
5.	Packed Cell Volume (%)	25.0–45.1 (34.1)	27.3–48.3 (37.6)	23.0–44.1 (33.3)	27.9–41.0 (32.8)	27.1–45.3 (37.2)
6.	Erythrocyte Sedimentation Rate (mm/hr)	0.7–2.3 (1.4)	1.9–3.7 (2.9)	1.7–4.1 (3.0)	2.1–4.2 (3.4)	1.7–5.1 (3.4)
7.	Mean Cell Volume (fl)	86.4–146.9 (103.6)	142.2–230.8 (192.5)	129.2–234.9 (181.7)	130.0–225.3 (175.5)	156.6–335.9 (232.2)
8.	Mean Carpuscular Haemoglobin (pg)	22.4–51.5 (37.1)	41.1–88.3 (65.0)	48.9–88.6 (68.4)	47.0–87.4 (63.8)	42.2–114.6 (75.1)
9.	Mean Carpuscular Haemoglobin Concentration (g/dl)	20.8–50.0 (32.8)	21.3–53.9 (34.7)	27.2–51.9 (37.7)	23.9–51.2 (38.2)	22.5–52.4 (35.0)

Values in parentheses represent mean of the recorded range.

collected from polluted sites had reduced body size. It was also observed that during winters all sites except Phaphamau showed abundant population of fishes. In summers, only Shringverpur showed abundance of fishes, while during monsoons the population of fishes was observed to be poor at all the sites and during post-monsoon period, all the sites except Phaphamau showed good population of fishes. During the course of the present studies, the low population of fishes at Phaphamau site may be due to the low DO at this site which has caused them to migrate to areas where DO concentration is higher. Similar observations have been reported by Akolkar (1981).

3.5. Food and Feeding Habits of Certain Gangetic Fishes

Food and feeding habits of eighteen different fishes belonging to seven families as evident from their gut contents was studied. On the basis of the observations the studied fishes may be classified into three groups : Herbivorus (*Labeo bata, L. calabasu, L. dero*). Carnivorus (*Wallago attu, Mystus bleekeri, M. seenghala, M. tengara, Rita rita, Eutropiichthys vacha, Clupisoma garua, Glossogobius giuris*) and Omnivorus (*Mastacembelus armatus, M. pancalus, Notopterus notopterus, Mystus aor* and *Mystus cavasius*). It may thus be concluded that the fishes were highly adaptable in their feeding habits as suggested by Khanna (1980).

3.6. Haematological Studies of Gangetic Fishes

Haematological values of certain fishes collected from the river at the selected sites were studied to assess the health of these fishes as affected by the deteriorating water quality. The haematological parameters studied have been recorded in the Table 21.8.

The values of haematological parameters studied in this laboratory might be due to the effect of toxic substances present in the river Ganga. Sinha (1988) reported higher concentration of heavy metals in Ganga waters which may be due to discharge of sewage and effluents from various factories, tanneries, textile mills, etc. Besides the environmental stress on food chain system and feeding intensity of the fish, metals, pesticides and other types of toxicants present in the Ganga water get accumulated in the various organs of the fish, causing internal injuries and ultimately affecting their normal health which may lead to deterioration in haematological conditions. Our conclusions thus support the contentions of Mukhopadhyay *et al.*, (1987), Culabrese *et al.*, (1975) were of the opinion that the deterioration of haematological condition in fish might be indicative of stress in the environment of the fish.

3.7. Biomass and Moisture Content of Certain Gangetic Fishes

Studies on the biomass and moisture content of a few fishes collected from the selected sites revealed that the quality of water did affect these parameters. It was concluded that fishes collected from polluted sites showed lower biomass and higher moisture content while those from comparatively purer sites had higher biomass and lower moisture content.

3.8. Calorific Values of Certain Animals in Relation to Water Quality

It has been widely reported that the quality of water also affected the energic values of the animals. Calorific values of certain animals estimated by the method of Adoni *et al.*, (1985) has been tabled in Table 21.9.

It would be clearly evident from the Table that except the pollution indicator organism all other animals studied showed higher calorific values at comparatively purer sites and lower calorific values at polluted sites.

It was also revealed from the results that the animals which are secondary consumers or which are herbivorous showed lower energic value. According to Mishra *et al.*, (1985) the feeding habit of a particular organism may influence its cal/gm content. Nutrients get concentrated as they pass along a food chain in contrast to energy which flow progressively from lower trophic level to higher trophic level. Sitewise variation in the calorific values of animals studied under the present investigations might be due to variation in DO concentration, high metal concentration and presence of other pollutants. In case the water quality deteriorates further the animals may either migrate from the site or may adapt according to environmental conditions as suggested by Mishra *et al.*, (1985).

3.9. Protein and Carbohydrate Concentration in Certain Animals

Proteins and Carbohydrates - the energy containing compounds were estimated in the tissues of certain Molluscs (*Anodenta* sp., *Lamillidens marginalis,* and *Vivipara bengalensis*), Fishes

TABLE 21.9

Calorific Values of Gangetic Animals

Sl. No.	Name of Group	Name of Organism	Energic values at different sites in cal/gm dry wt.		
			Kare-Manikpur	Shringverpur	Phaphamau
1.	Arthropoda	*Macrobrachium lamarrei*	2568.8217	2239.8323	2239.8323
2.	Arthropoda	*Corixa* sp.	1086.1158	1088.3692	1086.1158
3.	Arthropoda	*Ranatra elongata*	881.0608	878.8074	878.5541
4.	Arthropoda	*Nepa*	989.2217	989.2217	986.9683
5.	Arthropoda	*Dragon Fly nymph*	2370.5267	2368.2733	2338.9798
6.	Arthropoda	*Chironomus larva*	2981.1852	2904.5712	3145.6799
7.	Mollusca	*Lamillidens marginalis*	2816.6905	3217.7872	2494.4612
8.	Mollusca	*Anodenta* sp.	2904.5712	2904.5712	2478.6876
9.	Mollusca	*Vivipara bengalensis*	2199.2719	2167.7250	2163.2183
10.	Mollusca	*Melanoids tuberculatus*	2201.5253	2278.1393	2198.3182
11.	Pisces	*Notopterus chitala*	2990.1986	2990.1986	2985.6919
12.	Pisces	*Notopterus notopterus*	2649.9424	–	2357.0065
13.	Pisces	*Labeo bata*	–	–	2938.3715
14.	Pisces	*Labeo calbasu*	2228.5655	2266.8725	–
15.	Pisces	*Wallago attu*	3247.0808	3298.9079	3238.0674
16.	Pisces	*Mystus seenghala*	–	2978.9318	2976.6785
17.	Pisces	*Rita rita*	3869.0060	3866.7527	3630.1507
18.	Pisces	*Eutropiichthys vacha*	3177.2268	–	3174.9735
19.	Pisces	*Mastacembelus armatus*	2188.0052	2233.0722	2174.4850

– = Sample was not available

(*Notopterus chitala, Labeo calbasu, Wallago attu, Mystus cavasius, Rita rita, Eutropiichthys vacha*, and *Mastacembelus armatus*) collected from the selected sites. Sitewise variation in the concentration of proteins and carbohydrates in the tissues of selected animals were observed indicating that the water quality plays an important role, thus supporting the contention of Tiwari *et al.*, (1989) that the characteristics of the environment also affected the physiological and biochemical activities of the animals.

3.10. Ecto and Endoparasites of Certain Animals

Parasites of certain animals collected from the selected sites in this stretch of the river were studied to know the health of the animals in view of the deteriorating water quality. It was revealed that the maximum number of diseased animals (Molluscs, fishes and reptiles) were collected from Phaphamau indicating the increase in susceptibility of the hosts in view of poor water quality.

4. MASS BATHING STUDIES

In view of the fact that the river Ganga is respected as 'Goddess' and 'Mother' by devout Hindus, mass bathing occurs on important Hindu festivals. Mass bathing studies were conducted to study its impact on the physico-chemical and biological parameters.

4.1. On Shivratri at Haudeshwarnath

Impact of Mass Bathing at Haudeshwarnath – seat of a Shiv temple – on the occasion of Shivratri on certain physico-chemical (*p*H, conductivity, Turbidity, Total Solids, BOD, DO, COD, Alkalinity, Chlorides, Hardness, Phosphates, Sulphates, Nitrates and Fluorides) and biological parameters (MPN/100 ml. of total coliform, Faecal Coliform, Faecal streptococci, SPC/ml, phytoplankton density, Zooplankton and benthos density) was studied. Samples were collected from three selected sites: Site - I where no bathing took place, Site-II where mass bathing took place and Site - III : 100 meters down stream of Site - II. Initially water samples were collected from all the three spots before mass bathing started but thereafter when the bathing was at its peak samples were collected only from Sites I and III, Mass bathing was observed to cause an increase in certain parameters like turbidity, total solids, BOD, COD, Chlorides, total alkalinity, phosphates, MPN/100 ml. values and SPC/ml values and decrease in DO, Phenolphthalein alkalinity, Zooplankton, Phytoplankton and benthos density, while the values of *p*H, hardness, sulphates, nitrates and fluorides were not markedly affected. It may thus be concluded that mass bathing causes deterioration of water quality.

4.2. On Mauni Amavasya, Magh Purnima and Maha Shivaratri, 1989 Phaphamau

Phaphamau – the gateway to Prayag where Mahakumbh occurs every 12 years - was selected to study the impact of mass bathing in the river before it enters Prayag. Since Mahakumbh was celebrated in 1989 during January – March at Prayag, and since a large number of people who could not make it to Prayag on these auspicious occasions, take a dip in the river at Prayag, the mass bathing studies were conducted. The observations of these studies were more or less similar to those described above.

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22

Physico-chemical Studies of the Ganga Water at Kanpur (Kannauj to Shuklaganj Sector)

U. K. PANDEY

The results reported in this chapter were obtained during a study of the physico-chemical aspects of the river Ganga from September 1987 to August 1989. Ten sampling stations were selected for the study of water quality.

Monthly samples of the pure Ganga water (S_1), mixture of nala water and Ganga water (S_2) and nala water (S_3) have been collected from ten sampling stations (Figure 22.1; Table 22.1) and analysed for the following physico-chemical parameters : Turbidity, Electrical Conductivity, *p*H, DO, BOD, COD, Alkalinity, Total Hardness, Calcium Hardness, Magnesium Hardness, Chlorides, Kjeldahl nitrogen, Nitrite nitrogen, Nitrate nitrogen, Sulfate and Sodium (Table 22.2). The yearly averages for all these parameters (from September 1987 to August 1988 and from September 88 to August 89) in the pure Ganga water, mixture of nala water and Ganga water and nala water are given in Tables 22.2 and 22.3 respectively. Turbidity, BOD, COD, nitrogen and sulfates showed minimum values and DO and sodium the maximum values for the pure Ganga water indicating that the river water is less polluted when compared to nala water and mixed water.

Pollution of the Ganga River at Kanpur

(i) About 16 nalas collecting sullage water, sewage, textile waste, power plant waste and tannery effluents are discharged without any treatment into river.

(ii) The drain starting from the Zoo gate discharges the entire water including a part of sewage, sullage near Jageshwar Temple. Though the main current of river is several kilometres away from the point where this nala meets the river bank, it meets it near Bhagwat Das ghat. Another nala near S.D. College taking discharge of old Kanpur Abadi and Azad Nagar, discharges into the river directly. Since the sewer line, existing sewage and pumping station are not adequate to lift the entire sewer water from the sewer line, a part of it finds way into this nala.

Sisamau nala is a very major drain carrying sullage water as well as sewage water starting from Cooperganj collecting water at Benajhaber and at Partbti Bagla road. Bhairo Ghat nala and Cremation Ghat, which are just downstream the main pumping station for raw water supply for Kanpur, is yet another major source of pollution. The unclaimed dead bodies also find solace in the river Ganga.

Another nala running through the Meston Road also discharges directly into the river.

(iii) The dairies located in the city have a cattle population of about 80,000. The dung, fodder waste and other refuse from this cattle population together contribute quantitatively more than the sullage from the city human population of over 20 lakhs.

All these find their way into the sewerage system and the nalas in the rainy season and also totally choke many branches of the sewers and trunk sewers resulting in the overflow of the system.

(iv) Night soil collected from the unsewered areas of the city is thrown into the nalas which is also discharged into the river.

(v) There are about 160 tanneries in Jajmau whose effluent is directly discharged into the river. Major nalas which collect the effluent are Dabka nala (Golf nala), Sewen tannery nala and Super tannery nala.

(vi) The total water supply in Kanpur is about 55 mgd. After use, major part of it goes down the drain, nalas and sewers ultimately discharging in the Ganga. Sewage is taken to Jajmau sewage pumping station and 50% of it is being supplied to

TABLE 22.1

Data regarding Sampling Stations of the River Ganga from Kannauj to Shuklaganj (Kanpur)

Sl. No.	Sampling Stations	Longitudes (East)	Latitudes (North)	Elevation above Sea level ft.	Inputs with-drawal	Distance between sampl. stations km	Agri-culture	Industries			Urban centre	Domes-tic waste	Indl. waste	Agri. return waste	Orga-nised Bath-ing	Unor-ganis-ed Ba-thing	Cre-ma-tion	Body thro-wing	Navi-gation (Boat)	Fish-ing
								S. Scale	M. Scale	L. Scale										
1.	Kannauj U/S before Manimau Bridge	79° 55′	27° 20′	412.0	–	–	–	–	–	–	–	–	–	–	–	Yes	–	Yes	Yes	Yes
2.	Kannauj D/S after Manimau Bridge	79° 55′	27° 20′	412.0	Yes	0.30	–	–	–	–	–	Yes	Yes	Yes	–	Yes	–	Yes	Yes	Yes
3.	Samsu	80° 20′	26° 34′	410.5	–	26.00	Yes	–	–	–	–	–	–	–	Yes	Yes	—	Yes	Yes	Yes
4.	Bithoor	80° 20′	26° 34′	410.5	–	22.00	Yes	–	–	–	–	Yes	–	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5.	Rani ghat	80° 22′	26° 28′	410 0	–	16.50	Yes	–	–	–	Yes	–	–	Yes	Yes	Yes	–	–	Yes	Yes
6.	Bhairo ghat (Main stream)	80° 22′	26° 28′	410.0	Yes	7.00	Yes	–	–	–	Yes	–	–	–	–	Yes	–	–	Yes	Yes
7.	Bhairo ghat (Canal)	80° 22′	26° 28′	410.0	Yes	0.70	Yes	Yes	Yes	Yes	Yes	–	–	Yes	Yes	Yes	Yes	–	Yes	Yes
8.	Guptarghat	80° 21′	26° 28′	410.0	–	1.50	Yes	–	–	–	Yes	–	–	Yes	Yes	Yes	Yes	–	Yes	Yes
9.	Bhagwat Das ghat	80° 21′	26° 28′	410.0	Yes	1.40	Yes	–	–	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10.	Old Bridge (Shuklaganj)	80° 21′	26° 28′	410.0	Yes	1.12	Yes	–	–	–	Yes	Yes	–	Yes	Yes	Yes	Yes	Yes	Yes	Yes

S = Small; M = Medium; L = Large

TABLE 22.2

Range and Mean Values of Physico-chemical Parameters of the Pure Ganga Water (S_1), Mixture of *Nala* and the Ganga Water (S_2) and Pure *Nala* Water (S_3)
(September 1987 to August 1988)

	S_1	S_2	S_3
Turbidity (N. T. U.)	91.98 (23.6 - 271.2)	116.11 (31.4 - 297.0)	115.71 (33.7 - 292.3)
Electrical Conductivity m mhos/cm	16.90 (5.21 - 31.95)	8.65 (0.51 - 35.82)	9.71 (0.48 - 34.58)
*p*H	7.90 (7.57 - 8.09)	7.70 (7.18 - 8.08)	7.86 (7.33 - 8.12)
DO mg/l	7.28 (5.51 - 8.76)	5.97 (4.11 - 9.32)	6.16 (3.67 - 9.87)
BOD mg/l	6.52 (2.94 - 12.54)	20.38 (7.41 - 42.55)	19.39 (7.17 - 35.52)
COD mg/l	20.24 (11.46 - 26.1)	42.43 (18.69 - 75.27)	37.94 (19.47 - 60.59)
Alkalinity mg/l as $CaCo_3$	167.66 (91.4 - 215.0)	174.31 (90.4 - 256.0)	168.10 (86.0 - 254.7)
Total hardness mg/l as $CaCo_3$	103.10 (82.6 - 149.1)	123.15 (80.0 - 235.8)	121.28 (79.2 - 204.6)
Calcium hardness mg/l as $CaCo_3$	95.36 (57.2 - 143.4)	114.98 (27.6 - 190.8)	111.80 (74.2 - 196.6)
Magnesium hardness mg/l as $CaCo_3$	8.36 (5.0 - 17.2)	9.20 (4.2 - 19.2)	9.45 (5.0 - 18.6)
Chlorides mg/l	27.63 (14.93 - 50.88)	41.27 (22.13 - 62.28)	40.35 (21.92 - 59.4)
Kjeldahl nitrogen mg/l	5.29 (0.94 - 19.46)	10.61 (0.83 - 35.95)	10.39 (0.28 - 34.69)
Nitrite nitrogen mg/l	0.10 (0.01 - 0.42)	0.04 (0.02 - 0.08)	0.03 (0.02 - 0.05)
Nitrate nitrogen mg/l	1.17 (0.15 - 0.83)	1.75 (0.27 - 4.98)	1.55 (0.3 - 5.19)
Sulphate mg/l	21.78 (11.2 - 29.15)	31.60 (12.3 - 46.1)	32.81 (12.72 - 53.4)
Sodium mg/l	4.67 (0.42 - 18.28)	2.04 (0.6 - 4.4)	2.20 (0.58 - 4.62)

TABLE 22.3
Range and Mean Values of Physico-chemical Parameters of the Pure Ganga Water (S_1), Mixture of *Nala* and the Ganga Water (S_2) and Pure *Nala* Water (S_3) (September 1988 to August 1989)

	S_1	S_2	S_3
Turbidity (N. T. U.)	107.31 (50.2 - 172.6)	136.83 (91.6 - 249.6)	123.53 (85.4 - 210.0)
Electrical Conductivity m mhos/cm	20.93 (9.84 - 28.9)	8.11 (0.49 - 29.09)	7.48 (0.4 - 28.43)
*p*H	7.47 (7.27 - 7.68)	7.59 (7.28 - 7.95)	7.82 (7.6 - 8.11)
DO mg/l	8.02 (5.63 - 16.24)	6.59 (4.55 - 8.63)	5.42 (3.36 - 7.56)
BOD mg/l	6.24 (3.0 - 16.44)	15.47 (8.71 - 30.34)	20.39 (4.0 - 35.75)
COD mg/l	20.59 (12.31 - 27.2)	28.89 (15.65 - 42.59)	35.27 (21.84 - 50.21)
Alkalinity mg/l as $CaCo_3$	160.26 (92.4 - 186.0)	148.0 (91.4 - 191.2)	126.03 (80.6 - 167.8)
Total hardness mg/l as $CaCo_3$	141.56 (77.6 - 252.0)	145.99 (94.2 - 199.2)	129.75 (84.4 - 189.2)
Calcium hardness mg/l as $CaCo_3$	126.10 (62.8 - 223.4)	115.06 (73.8 - 175.8)	114.03 (76.0 - 160.8)
Magnesium hardness mg/l as $CaCo_3$	15.12 (10.6 - 28.6)	30.23 (15.2 - 62.0)	14.53 (8.6 - 18.8)
Chlorides mg/l	19.01 (8.36 - 26.94)	21.35 (12.44 - 46.43)	17.67 (10.88 - 34.51)
Kjeldahl nitrogen mg/l	4.18 (0.51 - 8.17)	6.22 (2.05 - 11.01)	6.47 (2.55 - 15.82)
Nitrite nitrogen mg/l	0.06 (0.01 - 0.24)	0.21 (0.03 - 1.46)	0.21 (0.03 - 1.29)
Nitrate nitrogen mg/l	1.69 (0.07 - 4.07)	1.61 (0.01 - 6.74)	1.96 (0.01 - 7.85)
Sulphate mg/l	24.45 (12.24 - 35.66)	26.44 (12.54 - 38.17)	28.13 (14.19 - 45.44)
Sodium mg/l	1.57 (0.45 - 8.27)	1.36 (0.42 -3.55)	1.53 (0.68 - 3.62)

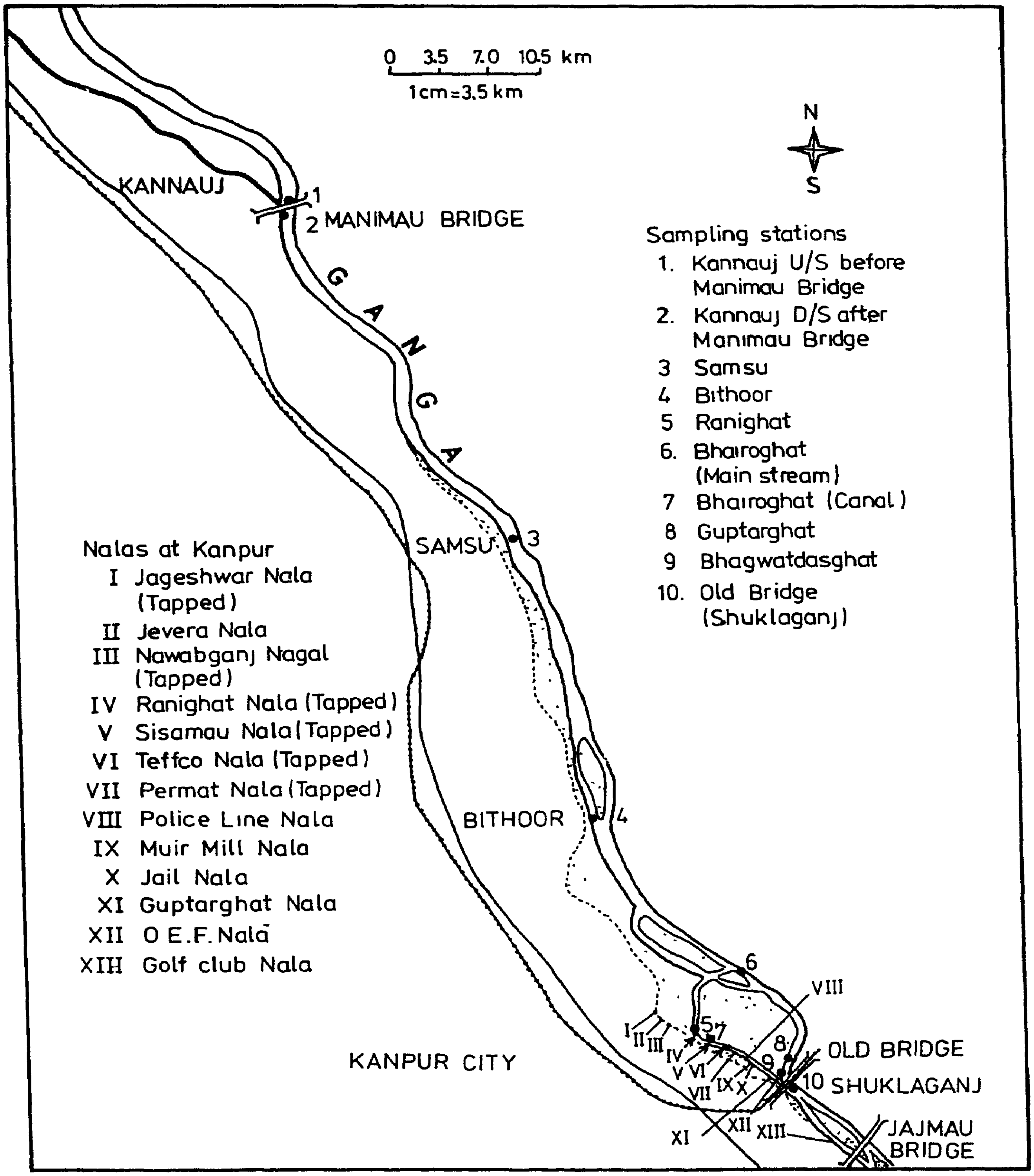

Figure 22. 1 : The Ganga River from Kannauj to Shuklaganj (Kanpur)

sewage farms after diluting it with raw Ganga water and the remaining 50% is discharged into the river. Thus, through nalas and sewers about 30 mgd of polluted waste water is discharged into the river without any treatment.

Nature of Outfalls

For pollution study of the Ganga river, samples were taken at various locations and the physico-chemical components are outlined below.

The sewerage outfalls at Jajmau alone contributed 1,52,000 cu.m/d of waste water putting an organic load of 31.16M tonnes of BOD and 81.40 M tonnes of suspended solids per day. Although, the volume of waste water carried from Guptar Ghat nala is half of Jajmau sewerage outfall, contribution of organic load in terms of BOD is however higher, the value being 35 M tonnes.

In terms of suspended solids the contribution by Guptar Ghat nala is 44.64 M tonnes/day. Sisamau nala carries about 45,360 cu m of waste water per day, contributing respectively 20.86 and 21.58 M tonnes of BOD and suspended solids per day. The three outfalls collectively contribute about 870 M tonnes of BOD and 147 M tonnes of suspended solids per day into the river. This is in addition to several other outfalls specially from tanneries, bringing untreated effluents from them to the river.

Observations of the Study

(a) TEMPERATURE, DO AND BOD – A PROFILE The peaks of BOD profile coincide with the troughs of DO percentage saturation levels and vice versa.

It is seen that even after a travel of 19.0 km the residual BOD in the river water at (station 9) Bhagwat Das ghat is higher than (and beyond permissible limit for raw water) the initial BOD at (station 1) Kannauj upstream before Manimau bridge; correspondingly the DO saturation levels are lower at station 9 than at station 1.

(b) DIFFERENT FORMS OF NITROGEN : Six monthly averages of different forms of Nitrogen viz., Total Kjeldahl Nitrogen, Ammonia Nitrogen, Nitrite Nitrogen and Nitrate for the different stations were studied. Looking at the profile of the behaviour of the different forms it may be observed that with the release of waste waters in the river all forms of Nitrogen have shown a steep rise followed by a decline as the river water travelled downstream.

Despite the progressive decline, the residual values of inorganic Nitrogen at station 9, the last station, are higher than those at station 1. This is with special reference to *Nitrite Nitrogen, which is a pointer of fresh pollution.* This would indicate that the organic pollution has not fully stabilized and mineralized.

(c) BACTERIOLOGICAL Six monthly average of bacterial counts of coliforms (confirmed) and *E.coli* at various stations as compared to the initial count of both coliforms (confirmed) and *E. coli* and the count at the last sampling station showed higher values which indicates that the river water at the last station Old bridge (Shuklaganj) could very well be a potential source of bacterial diseases specially enteric diseases, for the village folk who consume this water for various purposes.

23

Biological Studies of the Ganga Ecosystem between Kannauj and Shuklaganj

A. C. SHUKLA

Introduction

This report dwells on the results obtained on the studies of the Ganga Ecosystem between Kannauj and Shuklaganj. The complexion of Ganga between Kannauj to Shuklaganj is peculiar as bulk of the river in this stretch from Manimau to Bithoor traverses through an agricultural belt and thereafter at Shuklaganj through a highly industrialized part. As such in the agricultural zone, the river receives agricultural washouts of pesticides, fertilizers and insecticides but industrial effluents are impregnated at Shuklaganj. At Kanpur a specialized kind of industry, tanneries, is also located adding organic pollutants like hair, barks of tree, flesh-pieces and other tannery products. Major pollutants in the river comprise Ca, Mg, Fe, Mn, Na, SO_4, PO_4 Co, Ni, Cu, Pb, Zn, Cd and Cr along with host of organic products. DDT and BHC are also reported by investigators working on physico-chemical aspects elsewhere (Sinha, 1988). In view of these the water quality of the river is anticipated to show an increased pollutional content from Manimau to Shuklaganj with maximum pollution at Shuklaganj. Such a trend of total pollution load is not borne out by the individual parameters as reported by investigators working on physico-chemical parameters (Pandey, 1989). The river water is eutrophic with organic pollution.

The total and fecal coliforms present an indefinite pattern and a variance in time and space in this stretch. Larger coliform numbers was observed along banks with pockets with slow moving water as compared to midstream. Surprisingly, at the mouth of drainage channels spilling high degree of pollutants the MPN counts of coliforms was lesser.

It is of considerable importance to gauge public health hazards due to high levels of total and fecal coliform bacteria in lotic water of the river Ganga. It may be remarked that fecal coliforms form natural intestinal flora and pass out with fecal matter into the flowing waters. During present investigation both total and fecal coliforms exceed the limit of less than 5000 MPN/100 ml for drinking raw water source provided with conventional treatments and less than 500 MPN/100 ml for swimming purpose. Observations reveal a great deal of variance in MPN/100 ml of total and fecal coliforms throughout the calendar year at all the five stations namely, Shuklaganj, Bithoor, Nanamau, Araul and Manimau. The river in the midstream shows lesser bacterial count as compared to the water at banks. Out of five stations, it is observed that both total and fecal coliforms are less at Arual and Nanamau But the three stations Manimau, Bithoor and Shuklaganj show a high frequency of bacterial density (Table 23.1, 23.2) may be because the ghat is situated adjoining the populated area. This is due to continuous influx of sewage water and unending human activity which directly or indirectly makes the river polluted coupled with certain kinds of pollutant input load which also affects coliform levels at various places.

Total coliforms include fecal, enteric and other intestinal gram negative bacteria. Their existence in water beyond limit of pollutional hazard in the water causes dysentery, gastroenteritis, septicaemia and enteric fever in both human beings and animals, because they are always associated with pathogenic bacteria They are good indicators of fecal pollution in lotic waters. Assessment of fecal coliforms in the river stretch from Shuklaganj to Kannauj revealed that the water is unfit for direct consumption by human beings and animals except at Nanamau and Araul where the bacterial infestation is low.

Environmentalists are deeply concerned with concentration of pollutants in fresh lotic waters of rivers. Stresses caused by wastes have variety of effects on microbial community and water quality. Effect of Ca, Cu, Cobalt, Mn, Hg, Chromium, Lead and Nickel on multiplication of total and fecal coliform bacteria in

TABLE 23.1

Total Coliform Bacteria in Flowing Waters at Various Sampling Stations (1988-1989)

Sl No.	MONTH		MANIMAU		ARAUL		NANAMAU		BITHOOR		SHUKLAGANJ	
			A	B	A	B	A	B	A	B	A	B
1.	Oct.	Total	2200	3500	330	460	310	1400	1700	2200	1700	2400
		Fecal	1100	1700	330	330	130	940	1100	1400	1100	1300
2.	Nov.	Total	1700	3800	350	430	220	230	940	1700	1800	2800
		Fecal	790	2200	230	460	170	340	460	1300	940	1700
3.	Dec.	Total	1800	2200	230	280	170	280	700	1100	2800	3500
		Fecal	790	1100	130	210	110	230	460	790	1100	2800
4.	Jan.	Total	2200	2800	340	490	170	790	490	790	1400	2400
		Fecal	1300	1400	220	110	170	490	330	490	460	1400
5.	Feb.	Total	2200	3500	170	920	220	1300	460	700	1100	2800
		Fecal	1100	1100	130	170	130	260	210	460	330	1400
6.	Mar.	Total	2800	9200	230	1800	230	1800	790	1100	2400	9200
		Fecal	2200	2200	130	630	80	1400	270	700	1300	2400
7.	Apr.	Total	5400	5400	940	940	1400	1400	920	920	9200	9200
		Fecal	330	3500	460	460	790	790	490	490	240	2400
8.	May	Total	9200	9200	790	790	1800	1800	1700	1700	5400	5400
		Fecal	230	2800	490	490	630	630	700	700	180	1800
9.	June	Total	5400	5400	310	310	1200	1200	5400	5400	3500	3500
		Fecal	170	2400	430	430	900	900	790	790	240	2400
10.	July	Total	2200	3500	430	1100	430	630	1100	2200	2400	3500
		Fecal	1400	3500	230	700	170	220	330	1300	1200	2400
11.	Aug.	Total	3500	16000	700	1400	630	1800	3500	9200	3500	5400
		Fecal	1800	5400	490	700	260	1800	1400	3500	1800	3500
12.	Sept.	Total	2400	9200	630	940	790	1400	2200	5400	2200	3500
		Fecal	1300	2200	330	630	330	1100	1100	2200	1400	2200

A = Midstream B = Bank

TABLE 23.2

Occurrence of Keratinophilic Fungi and Dermatophytes at Different Stations of the Ganga

Sl. No.	Species	SHUKLAGANJ		BITHOOR		ARAUL		NANAMAU		MANIMAU	
		Occurrence	± SD (%)	Occurrence	± SD (%)	Occurrence	± SD (%)	Occurrence	± SD (%)	Occurrence	± SD (%)
1.	*Chrysosporium indicum*	31.42	± 0.40	–	–	37.14	± 1.16	29.6	± 0.51	26.6	± 0.51
2.	*C.tropicum*	37.14	± 1.16	24.3	± 0.51	31.42	± 0.40	37.0	± 0.51	30.0	± 0.18
3.	*C.evolceanui*	14.20	± 0.40	12.1	± 0.40	14.20	± 0.40	7.4	± 0.54	13.3	± 0.51
4.	*Microsporium fulvum*	11.40	± 0.51	26.8	± 0.40	5.70	± 0.51	11.0	± 0.54	13.3	± 0.51
5.	*M.gypseum*	–	–	14.6	± 0.63	11.40	± 0.51	14.8	± 0.81	6.6	± 0.51
6.	*Trichophyton simii*	5.70	± 0.51	14.6	± 0.63	–	–	–	–	10.0	± 0.54

lactose broth and EC medium was studied during present investigation. Observations reveal that response of bacteria to major pollutants is of considerable importance to unravel basic mysteries of Ganga eco-system vis-a-vis enteric disease spread. Experiments conducted showed that Fe, Hg, Ni, Cr, Co, Pb and Mn marvel remarkable depletion in MPN/100 ml of total and fecal coliform bacteria in higher concentrations. It may be emphasized that pollutional influx with substances cited above is likely to act on fecal and total coliforms in Ganga water. Except calcium all other substances result in remarkable depletion of coliforms. This fact suggests that while such pollutants act as nutrient for the growth of algae and macrophytes they also exercise control on coliform growth.

Pure bacteria free cultures of *Chrysosporium indicum, Trichophyton simu, Cladosporium herbarium, Fusarium poae and Alternaria fasciculata* were isolated from bottom sand of river Ganga. Response of these fungi to pollutants was studied *in vitro*. The major pollutants of river between Kannauj and Shuklaganj comprised Mercury, Lead, Copper, Chromium, Nickel, Cobalt, Manganese, DDT and BHC. The survey of literature indicates the response of different pollutants on growth and sporulation of certain fungi (Couey, 1965, Kusa, 1950, Richards, 1949; Treshow, *et al.*, 1969). Implications of increased pollutant influx into lotic waters was studied to assess response of fungi and plot futuristic fungal community in a river system under ever increasing pollution. This perspective is of vital importance to combat pollution due to fungal growth accompanying pollutant spills. Observations indicate that response of above mentioned fungi belonging to keratinophilic group shows sequential suppressed growth with concomitant increased concentrations from 10, 20, 50 to 100 ppm of pollutants. Such pollutants are impregnated in river water through industrial wastes and are likely to check proliferation of keratinophilic fungi causing dangerous diseases of hairs, hoofs, and horns of cattle or human beings.

Likewise certain fungi causing allergenic diseases are also prone for control due to influx of pollutants. Literature supports alteration in growth response of various algae to growth substances (Ahmad and Winter, 1968; 1970). Findings emphasize that several pollutants depress growth of fungi and coliforms in higher concentrations except calcium. While pollutants like lead and Zn deplete the growth of algae investigated, Ca promotes growth. It may, therefore, be remarked that changes in microbe community, reflects the pollutional quality and quantity in time and space. This may account for a vast variance in micro and macro-phytic growth.

Number of fungi was larger with increase in pollution levels from Manimau to Shuklaganj. The fact negates the hypothesis that with eutrophication the number of species declines but total infestation multiplies.

There is a good deal of variance in diversity and density of fish. Fish are constantly in migration and feed on algae in some stage or the other of their life. Preferential feeding behaviour of fish has been expressed through examination of gut content. 35 species under 17 genera of fungi spread over 27 species were isolated from fish fins and scales. Of these 15 species were from fish fins and 20 from fish scales.

Despite pioneering works of Cooke (1977), Cooke and Matsuura (1969) on fungal composition of fresh water ecosystems, little is known about fungi of fresh water bodies. There are few other reports on fungi of Ganga waters (Bilgrami and Dutta Munshi, 1979; Shanker and Prasad, 1983).

The occurrence of fungal spores and hyphae in Ganga waters indicate that they are capable of utilizing the nutrients from the polluted waters. Cooke and Matsuura (1969) reported an increase of 5-200 fold in the fungal and yeast populations within a year of operation of a stabilization pond, speaking thereby of the milieu of pond as a favourable habitat. In water ecosystem fungi occupy the same functional status as bacteria, bringing about effective degradation of phosphates and ammonia through domestic water (Patil, 1979). Fungi possess twin capability to reduce BOD as well. Presence of fungi and yeasts in the waters receiving organic enrichment is of pivotal importance in self-purification of water and cannot be simply ignored as casual contaminants (Cooke, 1973). Fungi observed during present investigation are crucial in biology of Ganga water and its self-purification.

The bottom sand of river Ganga is also not free from fungi. It supports 16 genera spread over 36 species. Qualitative abundance of fungi at Nanamau with 28 species is in close approximation of 27 species at Manimau, followed by 24 species at Araul and 15 species at Bithoor exemplifying variance in fungi of Ganga river. Species of genera *Cuninghamella, Mucor, Rhizopus, Chaetomium, Alternaria, Cladosporium, Curvularia, Aspergillus, Penicillium, Trichoderma, Phoma* and *Fusarium* comprise group of allergenic fungi. Such fungi cause Allergenic Rhinitis, Bronchial Asthma, Hyper sensitivity and Pneumonitis. Presence of these fungi in Ganga is of considerable significance as they infect both animals and human beings posing public health problems. The Ganga bottom sand was also studied with reference to keratinophilic fungi and dermatophytes. Dermatophytes are essentially related to diseases of the cutinized and keratinized parts of animals and human beings. However, keratinophilic organisms possess proteolytic enzymes capable of degrading keratinized substrates and keratinophilic organisms explicit competitive ability of keratin substrate in natural conditions. During past two decades enormous fungal diversity with special reference to keratinophilic forms has been investigated. The present study unravels the presence of three genera including 6 species namely *Chrysosporium indicum, C. tropicum, C. evolceanui, Microsporum fulvum, M. gypseum* and *Trichophyton simii* between Shuklaganj and Kannauj.

The isolation of pathogenic fungi from fins and scales of common major carps *Eutropichthys vacha* (Bachwal), *Mystus tengara* (Tengra); and *Rita rita* (Reetha), *Wallago* attu (Padin) were studied during present investigation. Fifteen species of fungi were isolated from fish-fins and 20 from fish-scales causing cutaneous and subcutaneous fungal infections. Fungi are reported to cause epidermophytosis, otomycosis, nocycosis, madura foot, aspergillosis, mucormycosis and pencilliosis in both animals and human beings. They are also likely to bring about degradation of fish scales and fins and in the process hasten fish mortality. Despite widespread public health hazard little is known about fish-pathogen inter-web. Fish mortality and fungus infections appear closely interlinked.

The fungi are also involved in the self-purification of water. During the present investigation six fungal species including *Bipolaris* sp., *Drechslera bicolor, Mortierella subtilissima, Botrytis terrestris, Gliocladium penicillioides* and *Cephalosporium acremonium* were recorded and are involved in self-purification of water. Algae are cosmopolitan in distribution but they exhibit a high degree of specificity of habitats and clearcut periodicity. Herein lies interest for studying biological profile of Ganga river forming intermeshing fabric of human life and its role in self-purification and pollution control.

A very large number of algal species amounting 577 species (comprising of 151 Chlorophyceae, 198 Cyanophyceae, 223 Chrysophyceae and 5 Euglenophyceae) has been recorded from this stretch reflecting a complex and wide milieu of river water. Total number of algae marks a declining trend from Nanamau to Shuklaganj except at Bithoor. Planktonic algae decrease from Manimau to Nanamau and then marks a sharp increase at Shuklaganj. A good deal of variance in the biological community complimenting changes in river water quality is witnessed. Growth of benthic and planktonic algae appear inversely proportional. The largest planktonic density 59628 cells per litre in March, has been observed at Shuklaganj. While major algae are implicated by their effect on the biology of water, minor algae are crucial to explicit minute changes in river water quality.

While studying dynamic habitats and algal distribution, there are two distinct categories of algae : benthic and planktonic forms.

A total number of 577 algal forms comprising many groups; 151 Chlorophyceae, 198 Cyanophyceae, 223 Chrysophyceae and 5 Euglenophyceae constituting 26.17, 34.31, 38.65 and 1.56 per cent respectively, from each class of algae could be recorded during present investigation.

The tropics are said to be the natural home of Cyanophyceae and their qualitative abundance has been recorded elsewhere by earlier investigators (Fritsch, 1907; Gupta 1957; Singh, 1961; Nair, 1965; Shukla, 1971 and Shukla, 1983). However, chrysophytes outweighed even Cyanophyceae during present investigation. Facts suggest that a large number of chrysophytes contribute to an increase in planktonic forms. However, number of species are not constant within fresh water environments (Anthony, 1970; Low, Davey, Lee and Baker, 1968 and Morrison and Fair, 1966).

The algal flora of the river Ganga shows a distinct periodicity and succession of algae. Among algal forms belonging to various classes, some of them grow throughout the year, others during larger span of time or short-lived and only recorded sporadically. Algae exhibit preferences for periodicity and succession in different seasons. Despite seasonal preferences they may continue to thrive in the transitory periods of seasons. Diatoms outweigh cyanophyceae and chlorophyceae at all the five stations.

Judging from contribution of algae in self-purification and for the sake of brevity of text only implications of major algae vis-a-vis periodicity and succession are considered of interest for discussion here. Major algal infestation exhibits qualitative diversity in time and space. A marked seasonal variance has been observed. On the basis of periodicity and distribution Algae may be grouped into summer, winter or rain annuals, perennials or ephemerals. Majority of them come up at certain period, thrive and endure unfavourable conditions in the form of spores or other means of perenniation. Apart from them there are certain algae not only confined to distinct season but exist as planktons and mud or bottom forms. Epiphytic algae except plankton remain attached temporarily or permanently. Predictably, attachment is through mucilage or specialized cells. There is also sequential periodicity and variance in different layers of water, making representative study more complex.

Qualitative assessment of algal growth in the river Ganga at Shuklaganj shows 24.26 per cent chlorophyceae, 34.50 per cent cyanophyceae, 39.89 per cent bacillariophyceae and 1.35 per cent euglenophyceae. The highest percentage occurrence in a calendar year was exhibited by diatoms followed by cyanophyceae, chlorophyceae and euglenophyceae. Monthly assessment of algae revealed profuse and abundant growth in the month of April and May with the least in August and September months.

Qualitative assessment of algae at Bithoor indicates that members of chrysophyceae outweighed both cyanophyceae and chlorophyceae. Results of a calendar year revealed 19 per cent of green algae, 33.5 per cent of blue-greens, 46.09 per cent of diatoms and 0.75 per cent of euglenophyceae. Dominance of diatoms over green and blue-greens, however, increased from winter to summer months. At Nanamau station also, the diatoms outnumber the green and blue-greens showing 26.33 per cent of chlorophyceae, 34.57 per cent cyanophyceae, 38.56 per cent diatoms and 0.53 per cent euglenoid occurrence in a calendar year. The highest algal density was recorded in the month of April and May and least in the month of July, August and September. Members of euglenophyceae were very rare and could be recorded once or twice in a calendar year. The summer-winter months show higher algal density as compared to rainy season.

Algal assessment at Araul ghat reveals 18.89 per cent of green algae, 43.30 per cent of blue greens, 37.32 per cent diatoms and 0.53 per cent euglenoids in a calendar year. Although, the average number of cyanophycean members is high in a calendar year yet monthly assessment revealed high density of diatoms during November to June surpassing the density of blue-greens during these months. At this station also, the algal density was recorded maximum in the month of April and May and the least in the month of August and September. At Manimau the qualitative assessment of algae revealed a similar trend as in other stations. In a calendar year the percentage of diatoms (48.33) was higher followed by blue-greens (27.66), green algae (23.00) and euglenoids (1.00). The month of April, May and June shows higher algal density while in the rainy season the algal number decreases in the river water.

Comparing the density of algae at five stations it becomes clear that diatoms were dominant throughout the year except for some time at some places. The occurrence of euglenoids was very rare and could be recorded only once or twice in the entire year. Results emphasize that winter summer seasons show high algal density which decreases during rainy season.

The annual changes in phytoplankton abundance and community structure occurs with some degree of predictability in temperate waters. However, the present findings are basic for lotic river waters in tropics. During winter seasons with low temperature, low light intensities and short days, phytoplankton biomass and productivity are generally low in spite of elevated nutrient concentrations. As the water warms and stratification begins to set in, the mixed layer becomes shallower and the algae are able to take full advantage of the nutrient stockpile. The algal bloom continues until nutrient depletion and increased predation signal the summer decline in phytoplankton production. In both fresh water and marine systems, diatoms are usually the dominant species of the spring blooms and are succeeded by chlorophycean, cyanophycean or dinoflogellates in more eutrophic situations.

The seasonal succession of algae involves the factors such as light, nutrients, temperature and grazing pressure of the water. It is likely that the decline in diatom abundance is related to the slow regeneration of silicate in the mixed layer at the metabolic level, the decline in the phytoplankton abundance during some months in a calendar year may be due to decrease in photosynthesis/respiration ratio. The preceding overview, while studied in a broad sense, does not seem to explain extensive changes in species abundance within the annual cycle. Success of any given species is likely to be unique to that species and will depend on its physiological capabilities and tolerance as well on the influence of other organisms preceding it and coexisting with it in the successional sequence.

While ascertaining predominance of algal assessment, quantitative abundance appears of vital importance. The total growth of algae appears more during winter season. During rains algal infestation marks a decline and in summers it is at its lowest ebb for some time when the temperature is high. Major components of algae which could be counted at Shuklaganj included 14 chlorophyceae, 7 cyanophyceae, 13 diatoms and 3 members of euglenophyceae. At Bithoor 9 green algae, 7 bluegreens, 10 diatoms and no euglenoids were observed. While at Nanamau the number was 13 chlorophyceae, 4 cyanophyceae, 12 bacillariophyceae and no euglenophycean forms. The Araul ghat exhibited 11 forms of chlorophyceae, 5 forms of cyanophyceae, 11 of bacillariophyceae and only one form of euglenophyceae. The river stretch at Manimau situated near Kannauj exhibited 10 chlorophycean, 6 cyanophycean, 1[illegible] bacillariophycean and no euglenophycean forms.

Total plankton density at five stations has been recorded. The highest plankton count at Shuklaganj was recorded in the month of March reaching its peak of 59628 cells per litre of river water and minimum in the month of August numbering 1589 cells per litre. At Bithoor, the highest planktonic count reached 44800 cells per litre with the least of 465 cells per litre in the month of December and August, respectively. The maximum and minimum planktonic density was 26600 and 730 cells per litre, respectively. The highest density was in March and lowest in the month of August at Nanamau. Quantitative assay of phytoplanktons at Araul is highest in January (25531 cells per litre) and least in the month of August (199 cells per litre). At Manimau, the planktonic density was highest in February reaching its peak of 38224 cells per litre and minimum of 398 cells per litre in the month of August. Results suggest the decline of planktonic growth during rainy season, whereas winter-summer season shows increased density at all the stations. Results are in conformity with the work of several other workers as mentioned previously. Appreciable variance in observations during present investigation from that of earlier reports is suggestive of the fact that in view to assess algal flora of a locality change in time and space should be accorded priority. Such changes in algal infestations appear to be induced due to alterations in dynamic features of environment.

Incidence of allergenic diseases due to algal allergens belonging to chlorophyceae and cyanophyceae have posed serious public health problem. Quantitative abundance of allergenic forms is directly linked with spread of allergenic diseases. Allergenic problems caused due to such algae are rhinitis, bronchial asthma, hypersensitivity, pheumonitis, bronchial provocations, mortality in fish, cattle and animals, coupled with symptoms of partial paralysis, loss of balance, hard stool, reduced milk yield, general weakness and photosensitization of skin. The allergenic algae observed in the river Ganga at five stations include *Chlorococcum humicola, C. infusionum*, *Chlorella vulgaris, Scenedesmus acuminatus, S. quadricauda, S. abundans, S. bijuga, S. arcuatus, Anabaena fertillissima, A. planktonica, A. iyengarii* var. *tenius, A. oscillarioides, Microcystis aeruginosa, Nostoc linckia* var. *arvense, Nodularia spumiqena, Oscillatoria anguina, O. limnetica, O. pseudogeminata var. unigranulata, O. okeni* and *O. formosa.*

Little is known about troublesome algae in drinking waters of various places, perhaps because historically, they have been known to be responsible for few problems directly affecting humans. On the other hand, bacterial and fungal infestations are known to cause considerable damage. But during recent years algae have acquired place of problem organisms in eutrophic waters (Trainer, 1978). Toxic characteristics exhibited by certain species (*Microcystis aeruginosa, Anabaena flos-aguae* and *Aphanizomenon flos-aguae*) are the best offenders. Water fowl, fish and livestock are the most frequently affected organisms though human deaths have also been reported. Another factor affecting bloom toxicity for all the three species is the relative proportion of toxic and non-toxic strains in the population. *Ulothrix* sp. and diatoms are some of the more troublesome forms (Evans, 1960 ; Edmondson, 1981).

Algae in general, because of their photosynthetic activity not only contribute to oxygenation of water but also constantly form a biological film and act beneficially in maintenance of water quality. They also pose problems of clogging, taste and odour and impair water quality. Algae are, thus, both useful and harmful for potability of waters.

Number of algae recorded in the observations were found growing in the river Ganga between Shuklaganj and Kannauj providing ideal fish food. Fish collected from Ganga were examined for algae in their gut content. Results emphasize algae forming an important food constituent of fish. Algal feeding to certain fishes of Ganga revealed that it induces better growth and productivity.

The planktonic growth is inversely proportional to benthic growth with former exceeding the latter at Shuklaganj a highly polluted stretch. Changes in benthic and planktonic growth and coliforms along the bank or midstream are enormous. Surprisingly, the total number of 577 algal species observed is very large by any standards and explicits Ganga as a vast resource of algal genetic stock.

Role of algae as bio-indicators of water quality like colour, odour, taste and other physico-chemical attributes is highlighted during present investigation and indicator organisms are listed. Macrophytic growth excelling at Shuklaganj expresses increased organic pollution and its significance in aquatic sports and swimming could well be anticipated.

Findings emphasize the role of bacteria, algae and fungi in self-purification of water on one hand but also give credence to the fact that such organisms are not only beneficial but also pose public health problems through allergenic, enteric and keratinolytic disease spread in either human beings or cattle.

Present findings on response of certain algae (*Stigeoclonium tenue, Phormidium tenue, Anabaena constricta*, *Oscillatoria acuta, Scenedesmus obliquus, Hydrodictyon reticulatum, Lyngbya martensiana* and *Mastigocladus laminosus*) isolated from river Ganga and subjected to common pollutants of river are in consonance with earlier reports.

Out of variety of pollutants tried, calcium promoted growth of algae as cited above, while lead depressed algal growth and zinc was stimulatory only in low concentration. Results emphasize that algal response to pollutants needs to be studied in greater detail to arive at some conclusions.

Growth of macrophytes is maximum (26 species) at Manimau and declines downstream up to Bithoor (26 species) but increases (28 species) at Shuklaganj. Macrophytic growth causes hindrance in swimming, bathing and boating. Growth of macrophytes could be harnessed as a source of proteins for obtaining extracts used in agriculture and used directly as manure. Ganga ecosystem supports vast treasure of micro and macrophytes together with fish fauna which could be exploited for dwellers of the Indo - Gangetic Plains. Water quality of the Ganga has tremendous self-purification capacity and is unique in more than one way.

Riverine ecosystem is a highly integrated ecologically complex system where the role of macrophytes is an important factor helping in maintaining ecological balance. During present investigation the macrophytes growing in the river Ganga and along the banks were studied. Aquatic macrophytes play a pivotal role in the primary productivity of river ecosystem. Bilgrami and Dutta Munshi (1979) have observed that biomass is directly related to productivity. They also observed that biomass was maximum at the centre where the primary productivity was greater and it was minimum where the productivity was lower. The number of macrophytes growing in and around the river Ganga is highest at Shuklaganj with the least numerical difference at Bithoor, Nanamau, Araul and Manimau. However, the diversity of species and their presence or absence varies from place to place. The assessment of macrophytes was done for the whole calendar year which marks the abundance of certain species in some months, while during some parts of the year show rare appearance. Comparatively, the months of July and August show rare appearance of macrophytes with thinner growth again in the month of June and September. Results indicate that the presence of macrophytes is witnessed throughout the stretch of river from Shuklaganj to Kannauj. Such reports have also been recorded from Shuklaganj to Kalakankar by Sinha (1988). Such organisms proliferate where organic matter is present in the ecosystem. Several workers (Chakraborty *et al.*, 1965) have studied the worst condition of polluted river water in the stretch passing through Kanpur city.

It is indeed needless to lay special stress on importance of algae in fisheries, for algae constitute basic link of food cycle of aquatic animals. In absence of algae a sustained fish productivity cannot be maintained (Patil, 1960).

There is considerable variance in diversity and density of fishes in river Ganga at Manimau, Nanamau and Shuklaganj in time and space. However, of the 32 fish species recorded most common edible fish of commercial value comprised *Eutropichthys vacha, Chela* sp., *Labeo bata, Labeo rohita, Puntius ticto, Wallago attu, Ophiocehalus striatus, Mystus tengara.* During present investigation gut content analysis of the two fishes viz., *Chela* sp., and *Eutropichthys vacha* was made to assess the algae consumed by fishes. Eighteen algal species were observed in the gut of two fishes. While *Synedra ulna, S. ulna* var. *aqualis, Nitzschia palea, Scenedesmus obliquus, Selenastrum westii, Ankistrodesmus falcatus, Chlorella vulgaris* and *Microcystis aeruginosa* were commonly found in gut of both the fishes, *Nitzschzia palea* var. *fonticola, Cymbella laevis, C. affinis, Navicula cryptocephala* and *Actinastrum hantzschii* were preferentially consumed by *Chela* species. *Navicula lanceolata, Cyclotella glomerata, Melosira granulata, Gleocapsa quaternata* and *Spirogyra* algae constitute an important fish food and there appears a preferential feeding behaviour of fish.

Discussion

Urbanization is the cause of pollution, as after use the water is discharged into the immediate surroundings and drained into the lotic waters of canals and rivers. Little is known about intricate interweb of the role of algae in flowing waters *inter alia* their desirability as troublesome or beneficial organisms forming a fine intermesh in the biological fabric of lotic waters. Historically, they have been known to be responsible for few problems as compared to the troublesome bacteria and fungi. But of late algae have acquired place of problem organisms in eutrophic waters (Trainer, 1978).

Perimeters of present investigation revealed interesting facts and provide new dimensions of importance to the prospects and aspects of self-purification in lotic waters of the Ganga river between Shuklaganj and Kannauj. Such knowhow has brought forth facts of both academic and applied significance. A correlative discussion of observations made during present investigation and facts recorded elsewhere in the literature would provide a conceptual synthesis of the subject matter. Bacteria breakdown remaining organic compounds and provide carbondioxide for algal growth. Algae take in phosphorus, nitrogen and other elements and release oxygen. Such biological activity manifests itself in the river Ganga and observations are suggestive of the fact that during summer reduction in water content and increase organic and inorganic load influx activates total and fecal coliform bacterial level coupled with algal infestation. Such intermeshed biological give and take in the riverine ecosystem naturally, helps in self-purification of water.

Conclusively, the totality of biological fabric of Ganga eco-system is very complex and rich. It could be exploited in multiple ways for the dwellers of Indo-Gangetic Plains. Variance and changes in its complexion are suggestive of the fact that the river has a tremendous capacity to assimilate and digest enormous amounts of pollutants. While it may be anticipated that there is an increase in pollution of river from Kannauj to Shuklaganj, the growth of coliforms, fungi and algae does not seem to express conventional complimentary pattern. Typically, increase in number of species with increase in pollution negates usual norms of eutrophication. Likewise, depression in coliforms at the mouth of certain drainage channels spilling pollutants needs greater attention. Such facts were correlated with *in vitro* response of algae, fungi and coliforms to major pollutants of the Ganga.

Present findings emphasize that while dealings with problems of river system, especially, pollution control and its monitoring on microorganism, growth in nature and in culture should be undertaken simultaneously to arrive at broad conclusions. Response of algae, fungi and coliforms to various concentrations of major pollutants should be studied in greater depth to prepare a strategy to combat forthcoming pollutional increase on the basis of past experience. Lastly role of algae and fungi as fish food and in disease spread of fins and scales respectively coupled with oxygenation of water is crucial for fish mortality and productivity. Preferential feeding behaviour of major and minor edible carps and its impact for raising fish productivity has considerable potential in fisheries development. Both algae as well as macrophytic flora could also be exploited as source for subsidiary protein food, for extraction of antibiotic substances and obtaining extracts to boost crop productivity.

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24

An Overview of the Hydrobiological Features of the Ganga in the Stretch Mirzapur to Ballia

B. D. TRIPATHI*

Sampling Sites

The stretch of the river covered in this study was from Mirzapur to Ballia. The nature and intensity of pollutants of the stretch was surveyed at Mirzapur, Varanasi, Ghazipur, Buxar and Ballia. City sewage, industrial effluents, detergents from cloth washing, input of organic content and solid wastes and dead body disposal constituted the main pollutants.

After visiting 24 sites, the following points were selected for regular sampling at Mirzapur : (i) a control site, the point before the river enters into the city. (ii) Vindhyachal, a religious place situated at the right bank of river Ganga. (iii) Khandwa *nala* situated 55 km downstream from Vindhyachal. The city sewage is discharged into the river through this *nala* situated between Rookhar ghat and Gaibi ghat. (iv) Narghat situated 0.4 km downstream from the Khandwa *nala* site, and in between Kot ghat and Gaughat. City sewage is also discharged through this *nala*. (v) Oliyar ghat situated at 1.5 km from the Nar ghat downstream of the river. A number of metal working industries are situated near the ghat. The metallic waste materials from aluminium and copper industries are brought here for filtration and separation. Two *nalas*, one at either side of this ghat discharge huge quantity of city sewage and industrial effluents into the river Ganga. (vi) Chunar, situated near the fort at about 30 km downstream from the Oliyar ghat and in between Varanasi and Mirzapur city. There is no sewer system in the town.

At Varanasi (25° 20'N latitude and 83° 1'E longitude) the middle of Gangetic plain, there are about 75 ghats situated at the left bank over a span of a 10 km crescent. About 1503 large, basic and small scale industries are located in and around the city. Most of them discharge their untreated effluents either directly or through the city sewer into the river Ganga. After surveying 13 points the following sites were selected :

(i) Control site situated at the upstream before the river enters into the city;
(ii) Assi ghat is the first and one of the most important ghats situated just after the Assi rivulet enters the city side. This ghat is mainly used for bathing, recreating, fishing, washing, drawing and drinking water. The main feature of this ghat is that a rivulet kind of drain enters just before the bathing site which bring industrial and domestic waste into the river.
(iii) Harischandra ghat for analysing the impact of discharge and cremation of dead bodies.
(iv) Chauki ghat for investigating sewage quality.
(v) Dashashwamedh ghat selected, for the analysis of sewage quality discharged and mass bathing.
(vi) Rajghat: Rajghat *nala*, the point of maximum sewage discharge into the river Ganga, situated downstream before the confluence of river Varuna

Ghazipur a poorly developed town in Eastern U.P lying on both banks of Ganga between 25° 19' and 25 ° 54' and 83° 4' N and 83° 58' E has 10 ghats out of which the following were selected for detailed study:

(i) Control site upstream before the river enters the city.
(ii) Opium factory, the major source of pollution discharged through an open drain into the river.
(iii) Nawapura situated 0.5 km downstream from Opium factory where sewage and some domestic wastes are discharged.
(iv) Dadri ghat situated at about 1 km from Opium factory site where city sewage is discharged through open drain.

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* Dr B D Tripathi was assisted in this study by Dr Rajani Kant Dwivedi, (RA), Mr A.K. Singh, Mr Suresh C. Shukla (SRF), Miss V Deepa Kumari, Mr V S Pandey (JRF), Miss Sushmita Mukherjee (Lab. Technician) and Mr Shripal (Lab. Assistant).

(v) Collector ghat situated 1.5 km from Nawapura is the biggest *nala* with significant quality of sewage.

(vi) Cheet Nath ghat situated at 1.5 km downstream from Collector ghat where city sewage is discharged through an open drain.

At Buxar, in Bhojpur district, Bihar, situated at the right bank of river Ganga (25° 3 N latitude and 83° 01′ E longitude) there are 9 cemented ghats situated along the bank of the river Ganga. For detailed study the following sites were selected:

(i) Control site upstream before the river enters into the town.

(ii) Taduka *nala* biggest *nala* and major source of pollution in Buxar.

(iii) Shakti ghat situated 0.5 km downstream from Taduka *nala* where city sewage is discharged through an open drain.

(iv) Gola ghat at 1.2 km from Taduka *nala* site where domestic and city sewage is discharged.

(v) Asptal ghat situated at 1.0 km from Gole ghat where again city sewage and hospital wastes are disposed.

Ballia, at eastern border of U.P. lies at 25° 44′ N latitude and 84° 11′ E longitude on the left bank of the river. The sampling site Prabodh ghat was selected near Cholhanpur village situated 22 km away from Ballia city on Ballia – Baria road.

Physico-chemical and biological properties were analysed at monthly intervals from August 1985 to March 1988. Results are expressed on seasonal basis i.e. rainy season from July to October, winter season from November to February and summer season from March to June.

Physico-chemical Properties of Water

TEMPERATURE

The lowest temperature of water 15.4° C was recorded at Chauki ghat site (Varanasi) during the winter of 1986-87 and the highest of 32.0° C at Chunar (Mirzapur) during the rainy season of 1987.

TRANSPARENCY

Usually the transparency of water at all the sites was lower than that of the corresponding control sites. The Secchi disc transparency of water at other sites was usually low during rainy season, increased gradually during winter attending peak in summer. The lowest transparency of water 11.7 cm was registered in the rainy season of 1986 at Khandwa *nala* (Mirzapur) and highest 86.5 cm during the summer of 1987 at the control site (Mirzapur).

*p*H

The *p*H values of water were recorded low during the rainy season and high during the summer season usually at all the sites. The lowest value 5.0 was recorded at Shakti ghat (Mirzapur) during the rainy season of 1987 and the highest, 8.40 during the summer of 1987 at the Opium site (Ghazipur)

DISSOLVED OXYGEN

Usually, at all the sampling sites, the highest value was recorded in the winter season

FREE CO_2

The highest concentration of free CO_2 41.5 mg/l was registered at Taduka *nala* in the summer season of 1986 and the levels were hardly detectable at most of the sites during the rainy season of 1985

TOTAL ALKALINITY

The values of total alkalinity at the control site were usually lower than those of other sites. The highest value was 447.5 mg/l during the winter season of 1987-88 at Rajghat and 10.4 mg/l at the control site in 1986 during the rainy season.

ACIDITY

At Mirzapur the acidity values ranged from 3.0 mg/l at the control site during the rainy season of 1985 to 34.9 mg/l during the summer of 1986 at Khandwa site.

ELECTRICAL CONDUCTANCE (EC AT 25° C)

The lowest ECs value 0.31 micromhos/cm was recorded at the control site of Ghazipur during the winter season in 1985-86. However, it was maximum at 1.54 micro mhos/cm at Assi ghat of Varanasi, during the summer season of 1986.

BIOCHEMICAL OXYGEN DEMAND (BOD)

The values at all the sites were uniformly higher than those of the control sites. The lowest BOD value 1.3 mg/l was recorded at the control site (Mirzapur) during the winter season of 1987 - 88 with a maximum of 201.9 mg/l at Assighat during the summer season of 1986.

CHEMICAL OXYGEN DEMAND (COD)

At all the sites the values were higher than those of the control sites. A value of 452.2 mg/l was recorded in the summer of 1986 at Rajghat and 4.5 mg/l at the control site of Buxar and Ballia during the winter of 1987-88. Usually at all the sites the highest values of COD were recorded in summer and lowest values during winter.

HARDNESS

The highest value of 280.0 mg/l was recorded in the summer season at Assi ghat in 1986 and the lowest 36.4 mg/l at the control site in the rainy season of 1986.

NITRATE – N

The lowest value 0.027 mg/l was recorded in the winter season of 1985-86 at the control site (Ghazipur) and 1.26 mg/l in the rainy season of 1987 at Opium factory.

PHOSPHATE - P

Maximum levels of phosphate were recorded during the rainy season throughout the investigation although a value of 0.29 mg/l was recorded at Dadrighat of Ghazipur in 1985.

SULPHATE

The highest value of sulphate recorded was 220.7 mg/l at Narghat (Mirzapur) during the summer of 1987 and the minimum 39.3 mg/l at the control site of Buxar during the winter of 1985-86.

CHLORIDE

The highest concentration of chloride of 156.5 mg/l was recorded in the winter of 1985-86 at the Opium factory of Ghazipur, and the lowest value of 8.5 mg/l at the control site of Mirzapur during the rainy season of 1986.

SILICATE

The lowest value of silicate 14.2 mg/l was observed at the control site of Mirzapur in the winter of 1987-88. The highest value of 40.68 mg/l was recorded at Opium factory in the rainy season of 1987.

TABLE 24.1

Phytoplankton species Recorded from Different Sampling sites from Mirzapur to Ballia from September 1986 to March 1988

Group I Algae recorded at Unpolluted Sites

(Total number of genera 31 and 42 species)

CHLOROPHYCEAE

Ankistrodesmus falcatus, Actinastrum hantzschii, Chlorella vulgaris, C. subsalsa, Cladophora glomerata, Closterium rostratum, Coelastrum sphaericum, Cosmarium dentiferum, Hydrodictyon reticulatum, Crucigenia truncata, Mougeotia sp., *Pediastrum simplex, P. boryanum, Scenedesmus acuminatus, S. bijuga, S. bicaudatus, Spirogyra subsalsa.*

BACILLARIOPHYCEAE

Amphora ovalis, Achnanthes clevei, A. microcephala, A. exigua, Cocconeis placentula, Cyclotella comta, C. meneghiniana, C. stelligera, Cymbella affinis, Fragilaria capucina, Gomphonema constrictum, G. parvulum, Gyrosigma acuminatum, Navicula gracilis, N. linearis, Pinnularia viridis, Surirella elegans, Synedra ulna, Tabellaria flocculosa, Diatoma elongatum, Melosira ambigua.

CYANOPHYCEAE

Phormidium inundatum, Oscillatoria limosa, O. limnetica, Merismopedia minima.

Group II Algae recorded at Moderately Polluted Sites

(Total number of genera 21 and 37 species)

CHLOROPHYCEAE

Chlamydomonas ehrenbergi, Cladophora glomerata, Chlorella vulgaris, Closterium incurvum, C. parvulum, C. paraceroeum, Coelastrum reticulatum, Cosmarium dentatum, C. undulatum, Scenedesmus falcatus, Pandorina morum, Ulothrix subtilisma, U. zonata.

BACILLARIOPHYCEAE

Cymbella turgida, C. ventricosa, Diatoma elongatum, D. vulgare, Melosira ambigua, Navicula cincta, N. cuspidata, N. gregoria, Nitzschia acicularis, N. amphibia, N. filiformis, N. palea, N. sigmoidea, N. tryblionella, Synedra acus, S. ulna.

CYANOPHYCEAE

Anabaena variabilis, A. cylindrica, Lyngbya limnetica, Merismopedia glauca, M. minima, Microcystis aeruginosa, Oscillatoria formosa.

EUGLENOPHYCEAE

Euglena gracilis.

Group III Algae recorded at Highly Polluted Sites

(Total number of genera 11 and 17 species)

CHLOROPHYCEAE

Chlamydomonas mirabilis, Scenedesmus quadricauda.

BACILLARIOPHYCEAE

Amphora veneta, Gomphonema clevei, G. parvulum, Navicula minima, Nitzschia communis, N. thermalis, N. palea, Synedra ulna.

CYANOPHYCEAE

Oscillatoria subbrevis, O. tenuis, Spirulina major.

EUGLENOPHYCEAE

Euglena acus, E. viridis, Phacus acuminatus, P. pusillus.

Phytoplankton Distribution

A number of phytoplankton species belonging to Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenoidae were recorded at different sampling sites from Mirzapur to Ballia during the period from September 1986 to March 1988 (Table 24.1). The chlorophyceae was represented by 19, genera Bacillariophyceae by 2 genera, Cyanophyceae by 7 genera and Euglenoidae by 2 genera. The distribution pattern of the algal flora was influenced by the physicochemical properties of water and concentration of the domestic and industrial effluents at the sites. On the basis of frequency and density these taxa have been divided into three different groups :

Group I (Unpolluted)
Group II (Moderately polluted)
Group III (Highly polluted)

Group I was represented by the algal species observed at control sites at all the sampling stations throughout the investigation. This group contained 31 genera and 42 species. The maximum number was recorded for Bacillariophyceae (15 genera), followed by Chlorophyceae (13 genera) and lowest for Cyanophyceae (3 genera) Table 24.1.

The most common species observed at control site belonged to green algae which were *Ankistrodesmus*, *Closterium*, *Coelastrum*, *Chlorella*, *Pediastrum* and *Scenedesmus*. They were abundant from January to

TABLE 24.2

Aquatic Macrophytes and Plants Observed on both the Banks of the River Ganga from Mirzapur to Ballia (April 1987 to March 1988)

(A) Aquatic macrophytes :

1. *Aponogeton natans*
2. *Azolla pinnata*
3. *Ceratophyllum demersum*
4. *Chara* sp.
5. *Desmodium gangeticum*
6. *Eichhornia crassipes*
7. *Eleocharis palustris*
8. *Hydrilla verticillata*
9. *Ipomoea aquatica*
10. *Lemna minor*
11. *Marsilea quadrifolia*
12. *Najas graminea*
13. *Nitella* sp.
14. *Potamogeton crispus*
15. *P. pectinatus*
16. *Prinstia strateoites*
17. *Scirpus articulatus*
18. *Spirodella polyrrhiza*
19. *Vallisneria spiralis*

(B) Plants observed on both the banks of the river Ganga :

20 *Achyranthes aspera*
21. *Ageratum conzyoides*
22. *Alhagi pseudoalhagi*
23. *Argemone mexicana*
24. *Amaranthus spinosus*
25. *Calotropis procera*
26. *Cassia occidentalis*
27. *Cassia tora*
28. *Chenopodium album*
29. *Convolvulus argensis*
30. *C. microphyllus*
31. *Croton bonplandianum*
32. *C. sparciflorus*
33. *Crotolaria medicaginea*
34. *Cynodon dactylon*
35. *Cyperus rotundus*
36. *Datura alba*
37. *Desmodium trifolium*
38. *Dichanthium annulatum*
39. *Eclipta alba*
40. *E. prostrata*
41. *Euphorbia hirta*
42. *E. thymifolia*
43. *Evolvulus alsinoides*
44. *Grangea maderaspatana*
45. *Heliotropium indicum*
46. *Launea asplenifolia*
47. *Lindernia crustacea*
48. *Melilotus indica*
49. *Phyla nodiflora*
50. *Phyllanthus niruri*
51. *Polygonum plebeium*
52. *Ranunculus scleratum*
53. *Ricinus communis*
54. *Ruellia prostrata*
55. *Rumex dentatus*
56. *Saccharum munja*
57. *S. spontaneum*
58. *Scirpus* sp.
59. *Solanum nigrum*
60. *Solanum xanthocarpum*
61. *Tridax procumbens*
62. *Xanthium strumarium*

June. *Chlorella* and *Chlamydomonas* were observed at all the polluted sites. The Bacillariophyceae were prominent during winter months. *Gyrosigma*, *Navicula* and *Synedra* were recorded throughout the year. The most abundantly found species were *Navicula* and *Nitzschia*. Members of Cyanophyceae were quite luxuriant at all the polluted sites. *Oscillatoria* and *Spirullina* were most abundant genera of this class. The maximum growth of Cyanophycea members were observed during summer and it was absent during the rainy season due to high velocity of water current. *Oscillatoria* and *Microcystis* were abundant both in summer and winter seasons. The *Euglenoids* were found only at highly polluted sites. Two genera *Euglena* and *Phacus* were observed in this group.

The Phytoplankton Density

The phytoplankton density at all the sampling sites was usually lower than that of the control sites. The lowest phytoplankton density was observed at Rajghat (Varanasi) in Septemper 1987 and the highest at control site (Prabodhghat, Ballia) in March 1988. At Mirzapur, values ranged from 5.12 × 10^4 individuals/l at Khandwa *nala* in August 1987 to 73.8 × 10^4/l at the control site in February 1988. At Varanasi values ranged from 3.14 × 10^4/l at Rajghat in month of September 1987 to 83.0× 10^4/l during April 1987 at the control site. At Ghazipur, density ranged from 6.15 × 10^4/l at Opium factory in August 1987 to 82.67 × 10^4/l at control site in April 1987. At Buxar and Ballia, values varied from 6.67 × 10^4/l at Asptal ghat in August 1987 to 85.46 × 10^4/l at Prabodhghat (Ballia) in March 1988.

Phytoplankton Productivity

The phytoplankton productivity of sampling sites was lower than those of the control sites. The highest value of gross primary productivity (GPP) was recorded during summer. *Euglena* and *Phacus* were the predominant genera recorded during summer at control site (Varanasi) and lowest at Rajghat (Varanasi) during the rainy season. At Mirzapur GPP values ranged from 0.247 gC/m^2/day at Khandwa *nala* in August 1987 to 2.47 gC/m^2/day at control site during March 1987. At Varanasi values varied from 0.234 gC/m^2/day at Rajghat in August 1987 to 2.48 gC/m^2/day at control site in March 1988. At Ghazipur values ranged from 0.274 gC/m^2/day at Collectorghat in August 1987 to 2.23 gC/m^2/day at control site in June 1987. At Buxar and Ballia minimum value was 0.03 gC/m^2/day at Taduka *nala* in August 1987 and maximum 2.40 gC/m^2/day at the control site in June 1987.

The net primary productivity (NPP) was highest at control site of Varanasi in June and lowest at highly polluted sites. i.e. Taduka *nala*, Rajghat, Khandwa *nala*. At Mirzapur the values ranged from nil at Khandwa *nala* in April and June 1987 to 1.92 gC/m^2/day at control site in April. At Varanasi, the highest value 1.98 gC/m^2/day was recorded at control site in June 1987. However, the value dropped almost to nil during most of the months except some of rainy season months at Rajghat (highly polluted site). At Ghazipur, minimum value was 0.22 gC/m^2/day at Collectorghat in August 1987. At Buxar and Ballia the value was maximum 1.74 gC/m^2/day at Prabodhghat in March 1988.

Aquatic Macrophytes and Plants

The record of these resources for the stretch studied is summarized in Table 24.2.

25

Community Structure, Biomass Production and Energy Aspects of Aquatic Macrophytes and Soil, Water and Nutrient Conservation of the Ganga

R. S. AMBASHT*

Aquatic macrophytes, riparian non-aquatic vegetation for their community organization, biomass structure, rates of biomass and energy production, soil and water analysis and soil conserving efficiencies of riparian vegetation at selected sites of the Ganga from Mirzapur to Ballia formed the subject of a study the results of which are summarized in this chapter.

The study was carried out at two levels – (i) an extensive study at bimonthly intervals at Vindhyachal, Mirzapur, Chunar, Kaithi, Ghazipur and Rudrapur (Ballia), and (ii) an intensive monthly samplings at two places at Vijuriavir Ghat near the University in the upstream southern fringe of Varanasi and at two places at Rajghat in the downstream northern periphery of the city just before the city sewage main discharge point (Figure 25.1). Standard methods of sampling, measurements and physico-chemical analysis were followed. At Varanasi phytosociological analysis of aquatic and riparian macrophytes was separately carried out at monthly intervals for the summer and winter seasons while during the rainy season due to high flood, swift water current, high turbidity, submergence of riparian slopes, no plant samplings were possible. Biomass analysis and rate of production in terms of net biomass and net energy fixation were carried out (on oven dry weight and energy content per unit dry weight) for both the aquatic and terrestrial macrophytes separately for each species and each community. Physico-chemical analysis of soil and water were also conducted to quantify the level of effectiveness of selected riparian species in preventing excessive soil, water and nutrient runoff from the shoreline into the river water.

Aquatic Macrophytes

Phytosociology : Aquatic macrophytes are the main primary producers of organic matter on which fishes thrive. They are also sources of oxygen which they produce during photosynthesis. They also act as harvesters of excessive nutrients and pollutants out of the water. Highly specialized hydrophytes thrive in certain segments of river with varying composition and density differing widely from place to place and from month to month. The two Varanasi sites viz., site IV Vijuriavir Ghat in the upstream and site V Rajghat in the downstream side have 10 and 8 species with a high similarity index level of 0.88. From monthly values of frequency, density and abundance certain seasonal trends could be seen in the component species and community. Four months of flood in the rainy season each year, restrict seasonal trend studies to summer (March – June) season I of 1986 and II of 1987 and winter season I (Nov. 1986 – Feb. 1987) and II (Nov. 1987 – Feb. 1988).

Species Composition and Frequency

Frequency refers to the degree of dispersion of each species and is the reflection of the percentage of occurrences in sampling units. It also refers to 'clumped' or 'even' distribution. At Vijuriavir Ghat there were seven species in 1986 summer and ten in 1987 summer. *Hydril-*

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*Prof Ambasht, Centre of Advanced Study in Botany, BHU, Varanasi was assisted in this study by Dr Shardendu (SRF 2-8-1985 – 4-1-1987, RA 5-1-1987 – 31-7-1988), A K Srivastava (JRF 2-8-1986 – 5-8-1987, SRF 2-8-1987 – 23-7-1988), Malay Shankar (JRF 6-8-1985 – 5-8-1987, SRF 6-8-1987 – 31-7-1988), Manju Sinha (JRF 27-1-1987 – 31-8-1988), H L Srivastava (Field Assistant 18-9-1985 – 9-3-1987), Shri Digambar Jha (Field Assistant, 27-4-1987 – 31-7-1988), Shri Ramji Prasad (Lab Assistant 18-9-1985 – 31-7-1988)

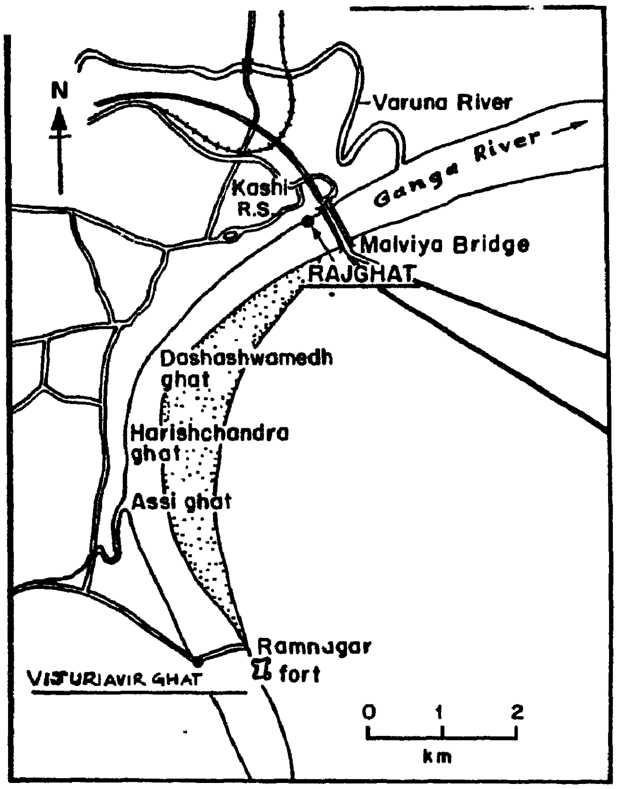

Figure 25.1 : Location of Study Sites

la verticillata, Najas graminea, Potamogeton crispus, Eichhomia crassipes and *Eleocharis palustris* occurred in both the years while *Aponogeton natans* and *Scirpus articulatus* were present in 1986 summer but did not come up in 1987; instead five other new species that appeared were *Potamogeton pectinatus*, *P. natans*, *Ceratophyllum demersum*, *Polygonum amphibium* and *Vallisneria spiralis*. Downstream at Rajghat before the sewer discharge point there was less diversity. At the sewer discharge region and further downstream upto the confluence of Varuna river, macrophytes were conspicuously absent. In summer 1986 only three species were recorded : *N. graminea*, *P. crispus* and *E. crassipes*. But in the the next summer (1987) the number of species increased to eight although their population density was lower than at V.V. Ghat. *Polygonum amphibium* and *V. spiralis* did not appear at Rajghat. The frequency percentage in summer 1986 ranged from 10 per cent in *Eichhomia crassipes* to 100 per cent in *Hydrilla verticillata* at V.V. Ghat and from 50 per cent in *P. crispus* and *E. crassipes* to 80 per cent in *N. graminea* at Rajghat. In the summer 1987 the frequency values have increased in most of the species at both the sites with 100 per cent for *Potamogeton crispus* at V.V. Ghat and 90 per cent at Rajghat. Index of similarity between the two sites in summer 1986 was 0.6 and in summer 1987 it was 0.88.

In the winter season of 1986-87 initially in November and December, only three species appeared : *H. verticillata N. graminea* and *P. crispus*. Their frequency percentage increased from November to February and the maximum 100 per cent value was obtained for *P. crispus* at V.V. Ghat and 80 per cent at Rajghat. In January and February 1987 two or three more species appeared on both sites, thus making the similarity index of 1.0 in the first winter. In the second winter season (1987-88) the diversity was 7 spp in November and December at V.V. Ghat and four at Rajghat and the similarity index was 0.72. In the next two months additional species also appeared making the total of 9 at V.V. Ghat and 6 at Rajghat and overall similarity index of 0.8 between the two sites. Frequency values in general showed an increasing trend from November 1987 to February 1988 in most of the species and a range of 20 per cent to 70 per cent. Besides *Polygonum amphibium* and *V. spiralis*, other species which appeared at V.V. Ghat but failed to appear at Rajghat were *P. pectinatus*, *C. demersum* and *P. amphibium*.

One possible conclusion from the composition and frequency results is that the above named three species are most susceptible to lower dissolved oxygen and pollution loads and their presence could be indicative of a relatively clean condition of water.

The numerical strength of different species in terms of number of individuals per unit area of sampled quadrats are referred as density and on per unit area of quadrat of occurrence as abundance. In the summer of 1986, the density of the community increased from 53 plants/m^2 in March to 82.7 in June at V.V. Ghat with an average of 70, while at the Rajghat the community density was much lower ranging between 11.2 to 27.8 with seasonal average of 20 plants/m^2. Among the components, *H. verticillata* and *N. graminea* had the highest density and abundance values at V.V. Ghat and *N. graminea* and *P. crispus* at Rajghat. In the second year summer (1987-88) the peak community density and abundance at V.V. Ghat was 327 and 394 plants/m^2 and at Rajghat 164 and 238, respectively. From February through May the values consistently increased. Among the components *P. crispus* had the highest density on both the sites and in all the months, the peak being 134 and 61 plants/m^2 in May 1987 at V.V. Ghat and Rajghat respectively.

In winter, the density values between the two sites became much closer and at Rajghat it even exceeded V.V. Ghat values in the second year. The community density progressively increased from 32 in Nov. 1987 to 85 plants/m^2 in Feb. 1988 at V.V. Ghat and from 38

(Nov.) to 126 plants/m^2 (in Feb.) at Rajghat and the average winter season density was 57 at V.V. Ghat and 78 plants/m^2 at Rajghat. But in the first year winter the community density was higher at V.V. Ghat ranging from 38 (Nov.1986) to 204 plants/m^2 (Feb.1987) and at Rajghat from 26 to 80 in the corresponding months and the average density was 98 at V.V. Ghat and 47 at Rajghat. Among the species, highest density in winter of both years was of *P. crispus* at V.V. Ghat and of *H. verticillata* at Rajghat.

From the density and abundance results of the second year of study it was seen that there was greater numerical strength than the first winter and at Rajghat the overall condition was more favourable than at V.V. Ghat. There was an overall increase in the number of species, frequency, density and abundance from 1986 to 1987-88 study years.

Biomass and Productivity

Aquatic macrophytes sampled every month from November 1986 to March 1988 in replicates of three from each point were oven dried and expressed as grams per metre square. From the positive difference in biomass between the successive months the rate of net primary production was calculated. The energy content per gram of dry matter for each species was estimated. Multiplying it with biomass production the rate of net energy fixation was calculated in form of organic productivity.

Biomass

At V.V. Ghat in summer (March-June 1987) there were ten macrophytic species although in the beginning there were only six (in March). The minimum biomass for different species was in the month of their initiations i.e. in November, December and January. Peak biomass was observed during July, 1987 for all the species. Values are given in Table 25.1. Maximum peak biomass was observed for *Potamogeton crispus*, followed by *Najas graminea*, *P. natans*, *P. pectinatus*, *H. verticillata*, *C. demersum*, *E. crassipes*, *P. amphibium*, *V. spiralis* and *E. palustris* at Vijuriavir Ghat. At Rajghat the peak biomass was in the order of *P. crispus* > *H. verticillata* > *N. graminea* > *P. natans* > *E. crassipes* > *C. demersum* > *P. amphibium* > *E. palustris*.

Rate of Biomass Production

P. crispus accounts for maximum production of 573 g m^{-2} yr^{-1} at Vijuriavir Ghat followed by *N. graminea* (435 g m^{-2} yr^{-1}), *H. verticillata* (361 g m^{-2} yr^{-1}), *P. pectinatus* (336 g m^{-2} yr^{-1}), *P. natans* (316 g m^{-2} yr^{-1}), *P. demersum* (197 g m^{-2} yr^{-1}), *E. crassipes* (193 g m^{-2} yr^{-1}), *P. amphibium* (118 g m^{-2} yr^{-1}), *V. spiralis* (70 g m^{-2} yr^{-1}), and *E. palustris* (70 g m^{-2} yr^{-1}). At Rajghat productivity values were higher for *P. crispus* followed by *N. graminea*, *H. verticillata*, *P. natans*, *E. crassipes*, *C. demersum*, *P. amphibium* and *E. pallustris* (Table 25.1).

Energetics

Average energy concentration was maximum for *P. crispus* (15166 J/g) followed by *N. graminea* (14911), *C. demersum* (14748) and *H. verticillata* (14388) at Vijuriavir Ghat while *H. verticillata* accounted maximum average concentration at Rajghat followed by *N. graminea*, *E. crassipes* and *P. crispus* (Table 25.1)

TABLE 25.1

Peak Biomass Values (July 1987), Productivity and Average Energy Concentration of Vijuriavir and Rajghat, March 1987 – March 1988

Species	Peak biomass (g/m^2)		Primary productivity (g/m^2/yr)		Energy concentration J/g	
	V.V. Ghat	R. Ghat	V.V. Ghat	R.Ghat	V.V. Ghat	R. Ghat
P. crispus	735.6	454.3	573	423	15,166	13,909
P. natans	396.2	199.9	316	195	–	–
P. pectinatus	382.1	–	336	–	–	–
H. verticillata	330.0	436.4	361	260	14,388	15,020
N. graminea	436.4	342.7	435	350	14,911	14,517
E. palustris	70.0	53.3	70	17	–	–
E. crassipes	184.9	150.3	193	183	14,748	14,328
C. demersum	198.4	120.6	197	116	–	–
V. spiralis	80.5	–	70	–	–	–
P. amphibium	147.0	96.7	118	53	–	–

Soil Water and Nutrient Conservation on the River Slopes and their input into the River Water in Relation to Riparian Macrophytes

Only seven different rainfall intensities (0.33 – 5.19 cm hr^{-1}) have been averaged here for the rainy season studies on riparian macrophytes raised in culture on sloping prepared by the riparian soil.

The quantity of precipitation, intensity infiltration, runoff of water, water conservation value of individual species, soil erosion and its input into the river bed, soil conservation values of selected plant species (a) *Xanthium strumarium*, (b) *Leucaena leucocephala*, and (c) *Sachharum bengalensis* and nutrient losses and input into the river were measured (Table 25.2).

An average quantity of 26 kg water/m^2 (range 2.09–47.03) precipitating on the experimental plots were recorded. Out of this 11.15 kg/m^2 was converted into runoff and 14.63 kg/m^2 was infiltered from an identical bare plot. The infiltration into the soil considerably increased to 18.74 kg/m^2 for *Xanthium strumarium*; *19.67 kg/m*^{2} for *Leucaena leucocephala* and 21.76 kg/m^2 for *Sachharum bengalensis*, and their respective water conservation values computed were 42.77 per cent, 53.33 per cent and 77.25 per cent respectively.

Soil loss quantities for bare and vegetated plots were separately collected, oven dried and weighed. The conservation value (CV) for soil for different species on average of seven readings are 58.47 per cent for *Xanthium strumarium* (range 48 – 73), 62.73 per cent for *Leucaena leucocephala* (range 47 – 74), and 83.47 per cent for *Saccharum bengalensis* (range 76 – 88 per cent), respectively.

With respect to nutrient losses and their conservation by riparian macrophytes, the conservation values of phosphorus for *Xanthium strumarium*, *Leucaena leucocephala* and *Saccharum bengalensis* were 43.06 per cent, 50.46 per cent and 82.17 per cent, respectively.

Biomass and Productivity Study of Riparian Slopes

Biomass (g m^{-2}) and productivity studies were carried out over a period of two years (1985-1987), in the three different zones (upper, middle, and lower) of riparian slopes of Rajghat and Vijuriavir Ghat. Here, the peak community biomass (g m^{-2}) and productivity (g m^{-2} season^{-1}) for winter (Nov. to Feb.) and summer (March to July) seasons are accounted for (Table 25.3).

Biomass and productivity at both Rajghat and Vijuriavir Ghat was high in winter. The values of biomass and productivity were same for the winter season due to continuous increment in the live weight after the flood receded in late rainy season. In summer biomass was much higher than the productivity values as a result of high loss in the form of litter and removal of plant parts by the local inhabitants and grazing.

Zonewise biomass and productivity on the riparian slopes clearly indicated that the values were higher in upper and middle zones than lower zones at both the sites. Biomass (1250.14 g m^{-2}) was highest in the upper zone in summer and productivity (1128.80 g m $^{-2}$ season $^{-1}$) in the upper zone in winter at Rajghat.

Biomass values were always higher at Rajghat compared to Vijuriavir Ghat.

TABLE 25.2

Water, Soil and Nutrient Losses in Relation to Riparian Macrophytes. Values are Average of 7 Natural Rainfall Intensities (Range 0.33 to 5.19 cm h^{-1}) Readings of Rainy Season 1988

Name of the species	Water Input (kg/m^{-2})	Runoff (kg m^{-2})	Infiltration (kg m^{-2})	CV water (%)	Soil loss kg/m^2	CV soil (%)	Phosphorus loss mg/m^2	P- CV (%)
Xanthium (P1) *strumarium*	25.78 (2.5 – 47)*	7.05 (1.4 – 24)	18.74 (1.1 – 34)	42.77 (13 – 65)	0.63 (0.18 – 1.00)	58.47 (48 – 73)	5.46	43.06
Leucaena (P2) *leucocephala*	25 80 (2.5 – 47)*	6.13 (0.8 – 21)	19.67 (1.7 – 35)	53.33 (24 – 79)	0.56 (0.17 – 1.00)	62.73 (47 – 74)	4.75	50.46
Sachharum (P3) *bengalensis*	25.79 (2.5 – 47)*	4.02 (0.4 – 15)	21.76 (1.9 – 37)	77.25 (44 – 95)	0.25 (0.08 – 0.48)	83.47 (76 – 88)	1.71	82.17
Bare (P4)	25.78 (2.5 – 45)*	11.15 (2.1 – 27)	14.63 (0.4 – 28)		1.34 (0.66 – 2)		9.59	

* Values in parentheses are the minimum and maximum ranges of all the seven different rain-intensity.

TABLE 25.3

Peak Community Biomass (g m^{-2}) and Productivity (g m^{-2} $season^{-1}$) of Rajghat and Vijuriavir Ghat for Winter (Nov. 1985 – 1986 and Feb. 1986 – 1987) and Summer (March 1986 – 1987 and June 1986 – 1987)

Season	Upper Zone		Middle Zone		Lower Zone	
	Biomass	Productivity	Biomass	Productivity	Biomass	Productivity
RAJGHAT						
Winter (1985 – 1986)	1012.50	1012.50	1105.50	1105.50	697.35	697.35
Winter (1986 – 1987)	1128.80	1128.80	985.20	985.20	793.76	793.76
Summer (1985 – 1986)	1065.72	76.78	1386.86	281.36	879.96	182.61
Summer (1986 – 1987)	1250.14	234.89	1175.46	190.26	940.37	146.61
VIJURIAVIR GHAT						
Winter (1985 – 1986)	888.76	888.76	850.25	850.25	566.82	566.82
Winter (1986 – 1987)	697.75	697.75	825.00	825.00	651.35	651.35
Summer (1985 – 1986)	927.23	38.45	1084.52	234.27	835.08	303.03
Summer (1986 – 1987)	976.35	278.60	875.15	50.15	1073.35	422.00

26

Environmental Impact of Irrigation by Canals in Mirzapur-Ballia Stretch of the Ganga

R. C. TIWARI[*]

The overall impact of the river water when diverted for irrigation on natural resources such as soils and agricultural crops was the subject of study reported in this chapter. The stretch between Mirzapur and Ballia districts covering about 255 km has 34 lift canals situated on its banks. Since their inception agricultural productivity of the region has substantially increased. However, information documented so far on the quality of irrigated water, its influence on the crops produced and on the physico-chemical properties of soil is very scanty. Six major canals out of the 34 were selected for the present study, which are enlisted in Table 26.1. Their location is indicated in Figure 26.1 with larger cricles.

TABLE 26.1

Details of Different Canals

Sl. No.	District	Location / Code (Pump canals)	Capacity (Cu sec)
1.	Mirzapur (DS)	Sakhaura (SKR)	60
2.	Mirzapur (DS)	Narainpur (NRP)	660
3.	Varanasi (DS)	Bhopauli (BPL)	480
4.	Ghazipur (US)	Deokali (DKL)	1050
5.	Ghazipur (US)	Zamania (ZMA)	720
6.	Ballia (US)	Korantadih (KTD)	50

US = Up Stream DS = Down Stream

The study envisaged

(i) variations (seasonal/monthly) in quality of lift canal irrigation water on the basis of chemical analysis;

(ii) the effect of lift irrigation water on some important physico-chemical characteristics of soils of the command area;

(iii) the effect of lift canal irrigation water on different crops grown in different soils as compared to tubewell irrigation of adjoining area; and

(iv) a subjective survey of the private farms of the Ganga lift canal command area to assess the response of farmers to the changes in agricultural practices particularly the influence of irrigation on soils, crop quality, crop substitutes and water table of the area.

Quality of the Ganga Lift Canal Irrigation Water

Proper care was taken in the collection, location, frequency, manner of sampling and parameters to be evaluated. Sampling frequency was once in a month. Sampling was done from three points of each canal.

The analysis and evaluation of water quality of samples were done as per methods given by Kanwar and Chopra and Manual of Water Analysis, Roorkee University using portable water analysis kit of Unibiochem (Madurai). In rainy season the water samples were found to carry mud and other suspended material. These were removed by filtration before analysis of the water.

Most of the parameters studied showed no significant changes within the sampling stations. Water quality for irrigation was found to be better in the monsoon season with the increased load of dissolved constituents. The only problem was suspended material which, however, settled down quickly causing silting.

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[*] Dr R C Tiwari was assisted in this study by Dr P N Tiwari, Research Associate (March 7, 1986 to Oct 7, 1987), Shri A K. Tiwari, Junior Research Fellow (Oct 18, 1981 to Oct 31 1985), A N Prasad, Junior Research Fellow (March 7, 1986 to Sep 15, 1987), Sanjay Tiwari, Junior Research Fellow (March 17, 1986 to April 18, 1988), R.D Dwivedi, Junior Research Fellow (Dec 1, 1986 to July 31, 1988) and Bharat Pandey, Field Assistant (April 1, 1986 to July 31, 1988)

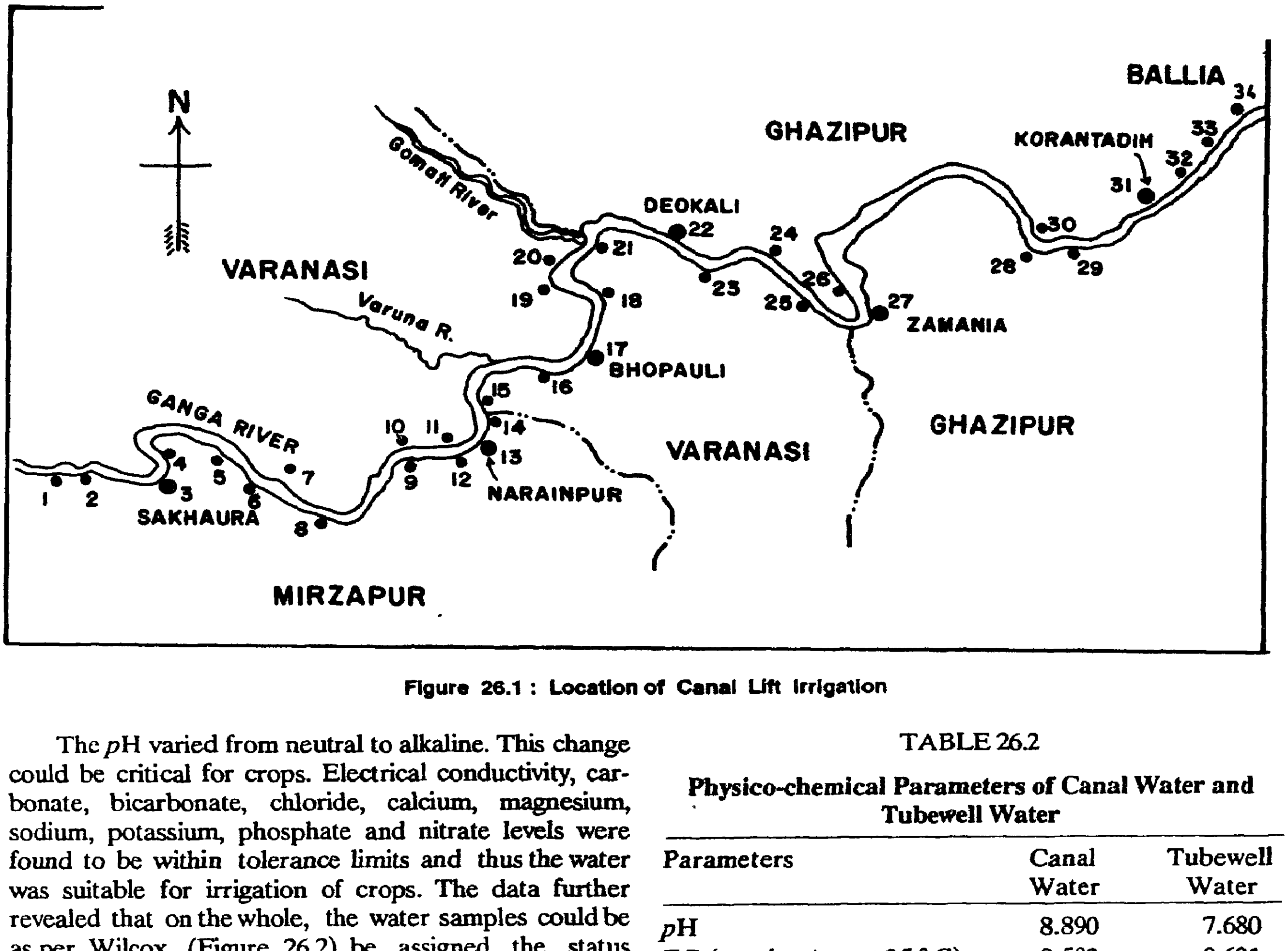

Figure 26.1 : Location of Canal Lift Irrigation

The *p*H varied from neutral to alkaline. This change could be critical for crops. Electrical conductivity, carbonate, bicarbonate, chloride, calcium, magnesium, sodium, potassium, phosphate and nitrate levels were found to be within tolerance limits and thus the water was suitable for irrigation of crops. The data further revealed that on the whole, the water samples could be as per Wilcox (Figure 26.2), be assigned the status of class C_2 S_1 which indicates that the water could be used for irrigation almost for all the crops with no chance of sodium accumulation. However, the moderately saline water (C_2) may be suitable only for crops on soils with less permeability. In heavy soils where permeability is low, irrigation may lead to salinity hazards.

The seasonwise observation of the data (mean of two year data of all canals) indicated that *p*H and EC of water collected during *Zaid* crop season (March – June, i e. summer) were higher than *Kharif* crop season (July – Oct., i.e. monsoon) whereas in *Rabi* crop season (November – February, i.e. winter) water samples showed medium values. A similar trend was found for micronutrients (Zn, Cu, Mn and Fe) in all the canal waters (Table 26.2).

Effect of the Ganga Lift Canal Irrigation Water on Different Soils of Canal Command Area

Soil samples were collected from the Ganga lift canal irrigated and adjoining tubewell irrigated areas. The sampling was done from three different points adjacent to the canals and three points near tubewell irrigated areas. Samples were collected from a depth of 0-15 m, processed and used for analysis.

The data collected revealed that the *p*H, electrical conductivity and organic carbon (per cent) of soils irrigated with the water of different canals from the

TABLE 26.2

Physico-chemical Parameters of Canal Water and Tubewell Water

Parameters	Canal Water	Tubewell Water
*p*H	8.890	7.680
EC (m mhos/cm at 25 ° C)	0.503	0.621
Dissolved solids (mg/l)	11.780	10.300
SAR	0.460	0.620
Total nitrogen (mg/l)	1.740	0.920
PO_4^{-3} (mg/l)	0.460	0.310
Ca^{+2} (meq/l)	1.540	2.740
Mg^{+1} (meq/l)	1.920	2.190
Na^{+1} (meq/l)	1.090	0.850
K^{+1} (meq/l)	0.950	0.370
CO_3^{-2} (meq/l)	1.000	6.540
HCO_3^{-1} (meq/l)	4.650	3.030
Cl^- (meq/l)	3.420	3.030

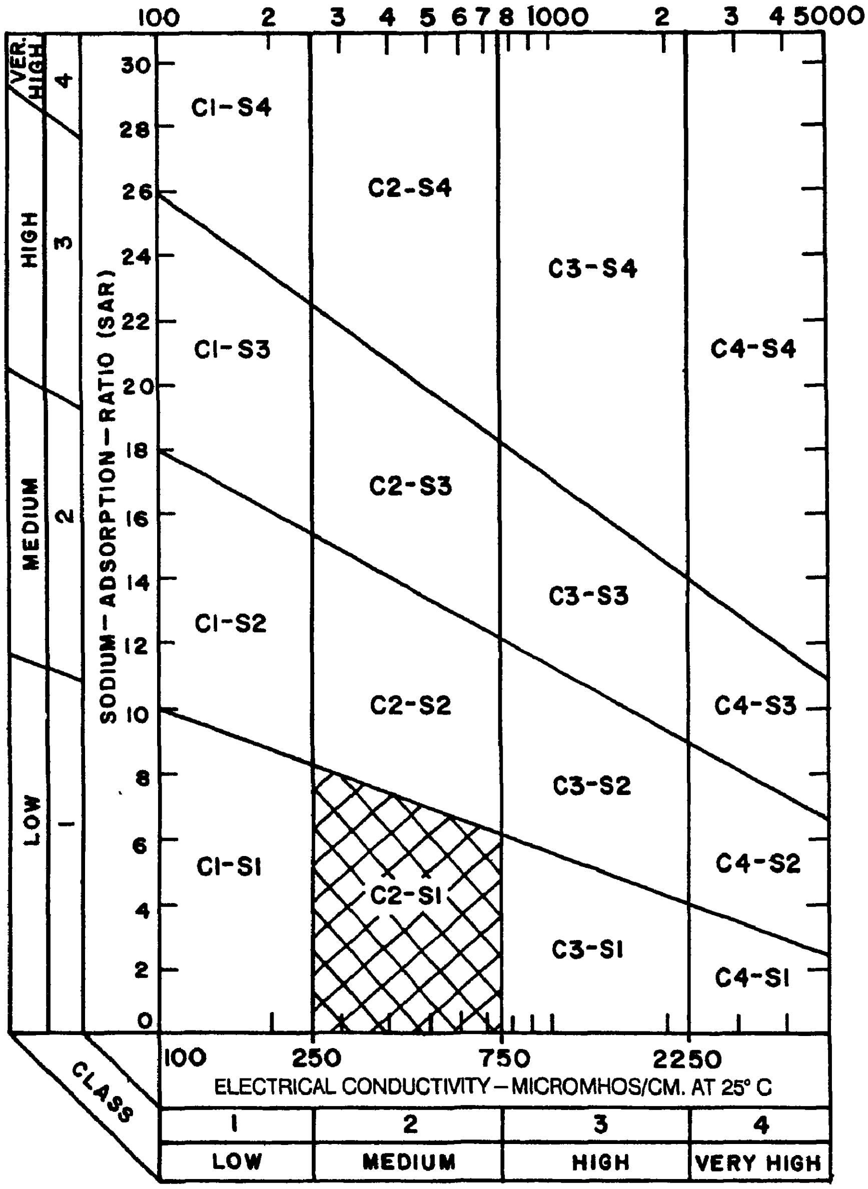

Figure 26.2 : Salinity Hazard

course of Ganga were relatively high as compared to the corresponding values for adjoining soils irrigated with tubewell waters.

The sand and silt percentages were higher in canal irrigated soil samples whereas the percentage of clay was found to be higher in tubewell irrigated soil samples

The contents of all three major nutrients (N, P, K in kg/ha) were found to be higher in canal irrigated soil samples. This may be due to relatively high amounts of plant nutrients in the lift canal waters.

Effect of the Ganga Lift Canal Irrigating Water on Different Crops (growth and yield)

The pot experiments reported in this chapter were carried out in the glass house of the Department of Soil Science and Agricultural Chemistry, during *Rabi*, *Kharif* and *Zaid* seasons (April 1985 - July 1988) to assess the response of Moong (T-44), Rice (Madhuri-IET-5725) and Wheat (HUW-234) to different canal waters. Keeping the same level of NPK the pots were filled with 10 kg farm soil. The soil was representative of Gangetic alluvium. The pots were arranged according to a Randomized Block Design. All the three pot experiments had seven treatments and were replicated five times keeping five plants in each pot.

The physico-chemical characteristics of experimental soils collected from the Agricultural Farm of B.H.U are given in Table 26.3.

TABLE 26.3

Characteristics of Soils Used

S.No	Parameters	Values
1.	*p* H	7.10
2.	EC (m mhos/cm at 25°C)	0.15
3.	Organic carbon (%)	0.35
4.	Available N (kg/ha)	148.00
5.	Available P (kg/ha)	15.00
6.	Available K (kg/ha)	182.00

Green Gram

The longest root length was observed in the pots irrigated with waters of SKR canal whereas maximum root volume was obtained in the case of BPL canal. The root weight was observed to be the highest in ZMA water irrigated pots. Largest number of nodules with maximum weight was observed in case of DKL canal water irrigated pots. The grain and straw yield was observed to be the maximum in the pots irrigated with waters of DKL canal. Thus, there was no regular trend found on the basis of intercanal studies. Mean values of parameters determined with all the six canals and tubewell water indicated that the lift canal water gave better results with respect to root length, number of nodules, weight of nodules, number of grain and straw yield than the tubewell water.

The higher yields of green gram due to the Ganga lift canal irrigated waters may be due to higher amounts of plant nutrients present in the Ganga water as pollutants. (Table 26.4)

Rice

All the critical values were found to be higher in canal irrigated pots than in those irrigated with tubewell water.

The highest plant height was observed in pots irrigated with SKR canal water. The root volume, root

TABLE 26.4

Effect of the Ganga Lift Canal and Tubewell Irrigation Water on Summer Moong (green gram)
Data based on Two Year Experiments (Values are per pot)

Irrigation with	Root			Number of nodules	Weight of nodules (gms)	Number of pots	Grain yield (gms)	Straw yield (gms)
	length (cm)	volume (cm^3)	weight (gms)					
Lift canal water								
(X) Mean	39.69	5.87	1.88	24.00	0.085	30.69	7.68	14.88
Tubewell water								
Mean	39.88	6.12	2.12	15.50	0.066	14.75	3.38	14.13

(X) Mean for six lift canals located between Mirzapur and Ballia.

TABLE 26.5

Effect of the Ganga Lift Canal and Tubewell Irrigation Water on Rice (observations / 5 plants)
Data based on Two Year Experiments

Irrigation with	Plant height (cm)	Root		Total number of tillers	Effective tillers	Grain yield (gms)	Straw yield (gms)
		length (cm)	volume (cm^3)				
Lift canal water							
(X) Mean	63.70	39.42	49.79	45.81	41.12	19.26	25.76
Tubewell water							
Mean	60.00	28.10	39.25	34.66	30.33	16.12	20.04

(X) Mean for six lift canals located between Mirzapur and Ballia.

length, total number of tillers and effective tillers registered maximum values in KTD, ZMA, DKL and SKR irrigated pots, respectively. The straw and grain yields were found highest in DKL and SKR water irrigated pots, respectively.

The grain yield and straw yield of canal water irrigated pots were significantly more than tubewell water irrigated pots. The root volume, total number of tillers and effective tillers were more in canal irrigated pots in comparison to tubewell irrigated pots but the difference was not significant (Table 26.5).

Wheat

The values for root length and root volume were generally higher in canal irrigated pots than in tubewell irrigated pots.

The grain and straw yields of canal irrigated pots were significantly more than those given by pots irrigated with tubewell. Highest grain yields were found in pots irrigated with NRP canal water whereas straw yields were relatively more in pots irrigated with KTD canal water. The mean values of all canal and tubewell water indicated that the Ganga lift canal water gave better results with respect to all yield attributing parameters except root length over the tubewell water (Table 26.6).

Subjective Survey of the Farmers of the Ganga Lift Canal Command Area

In order to assess the views of farmers of canal command areas on changes particularly the influence of irrigation on soils, crop quality and crop substitute, a subjective survey was conducted by interviewing 50 farmers of 5 villages of each canal command area. The following conclusions were drawn on the basis of views of the majority (more than 50 per cent) of farmers. Only those canal command areas were selected which had been in operation for more than a decade at the time of the survey :

(i) Quality of irrigation water is good.
(ii) Common crops grown by the farmers are mainly paddy, wheat and mustard (mixed with wheat), sugarcane, potato and some vegetables (on smaller scales).
(iii) Due to excess of water after the inception of canals, cultivated area under pulse and oilseed vanished. Before the inception of canals the crops grown were bajra, jowar, barley, pigeon pea, green gram, black gram, mustard, linseed, sesamum and sugarcane, but yields were low and fluctuating due to drought etc.
(iv) Quality of grain is reported to be good and the yields of straw in paddy and wheat have increased.
(v) The average yield of wheat ranges between 22 and 28 quintals/ha in comparison to 8-10 q/ha before irrigation started.
(vi) In the adjacent areas of canals the water table increase is about 70 per cent and in the distant areas from canals there is no effect on water table.
(vii) The orchards are destroyed due to excessive wastage of canal water logging and rise in water table.
(viii) Weed population has been found to be on increase in all seasons due to canal irrigation, e.g. *Falaris minor, motha, kaskutta, Parthenium etc.*
(ix) Winters are cooler after the inception of canals due to excessive water collected in command areas.
(x) The economic condition of the villages has improved after inception of canals.
(xi) Some important suggestions given by farmers to improve irrigation are :–
    (a) water should be available when needed;
    (b) water wastage and collection along canals should be controlled;
    (c) canals should be cleaned;
    (d) canals should be lined to avoid seepage.

TABLE 26.6

Effect of the Ganga Lift Canal and Tubewell Irrigation on Wheat (observations / 5 plants) Data based on Two Year Experiments

Irrigation with	Plant height (cm)	Root length (cm)	Root volume (cm^3)	Total number of tillers	Effective tillers	Grain yield (gms)	Straw yield (gms)
Lift canal water							
(X) Mean	69.20	38.68	38.25	9.65	4.48	12.85	69.73
Tubewell water							
Mean	63.90	40.90	37.55	7.30	2.75	5.41	66.30

(X) Mean for six lift canals located between Mirzapur and Ballia.

27

Assessment of Pollution Load on the Ganga in the Stretch Bally to Bandel

N.C. DATTA*

Results of a study of the state of health of the stretch Bally to Bandel of the Hugly are summarised in this chapter.

Study Area and Sampling Sites

The study area shown in Figure 27.1 lies between the latitude 22° 39′ North and 22° 56′15″ North and longitudes 88° 15′ 30″ East and 88° 33′ East comprising seventeen police stations The following spots were selected for sample collection :

	Western	Eastern
	Bank of the river Ganga	
Station – 1 :	Bally	Dakshineswar
Station – 2 :	Rishra	Khardha
Station – 3 :	Sheoraphully	Barrackpore
Station – 4 :	Chandannagar	Jagatdal
Station – 5 .	Bandel	Naihati

Figure 27.2 (a– c) represents the variations of selected physico-chemical parameters for the five Stations. The data for the entire period of study for the parameters indicated wide seasonal variations. For a given spatial or time interval, data from all the stations were combined and statistically treated as a single set.

Biochemical Oxygen Demand · The estimation of BOD was done at two stations (Stn. 2 and Stn.5) and the results are summarised in Table 27.1 The range of BOD at Station 2 was found to vary between 0.45 – 13.05 mgl^{-1} with an average value of 5.915 mgl^{-1}. At Station 5, the range was from 0.34 to a maximum of 9.90 mgl^{-1} with an average of 2.591 mgl^{-1}. When all the values of BOD were pooled the cumulative mean level of the same appeared to be 4.25 mgl^{-1}.

TABLE 27 1

Monthly Variations of BOD

Year/Month	BOD mgl^{-1} Station 2	Station 5	Mean
1986			
November	6.220	1.224	3.72
December	13.055	9.908	11.48
1987			
January	7.540	1.632	4.59
February	2.752	2.040	2.40
March	7.750	0.510	4.13
April	9.754	2.040	5.89
May	4.000	1.632	2.82
June	0.452	2.930	1.69
July	0.775	0.348	0.56
August	5.146	1.836	3.49
September	7.623	4.418	6.02
Mean	5.915	2.592	4.25
S.D.	3.630	2.600	2.77

Correlation of the diverse physico chemical factors in determining the water quality is brought out in

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* Prof Datta was assisted by the following staff in the present study Mr Biplab Kumar Bandyopadhyay –(SRF) Sept 1984 – Nov. 1986, Feb. 1988 – March 1988, Mr Nikhilaranjan Mandal – (SRF) Oct 1984 – Oct 1985, Dr Anjana Majumdar – (SRF) Feb 1985 – Oct 1987, Mr Sanjay Sukla – (JRF) Jan 1985 – June 1985, Mr Saumitra Ghosh Roy – (JRF) Sept 1984 – Aug. 1985, Miss Dhawanti Ahuja (JRF) Feb 1985 – March 1988, Mr Jawaid Siddiqui – (JRF) April 1987 – March 1988, Mr Parimal Roy, (JRF,) April. – Nov. 1987 Mr Bijoykali Mahapatra (JRF) Feb 1988 – March 1988

TABLE 27.2

Correlation of the Diverse Physico-Chemical Factors

	Water Temperature	Transparency	Specific Conductivity	pH	Carbondioxide	Total Alkalinity	Dissolved Oxygen	Salinity	Dissolved Organic Matter	Phosphate-phosphorus	Nitrate nitrogen	Silicate	Hardness	Calcium	Mg
Water Temperature	1.000														
Transparency	−0.455**	1.000													
Specific Conductivity	0.113	0.621***	1 000												
pH	0.721***	0.250	0.521**	1.000											
Carbondioxide	0.135	−0.290	0.535**	−0.744***	1.000										
Total Alkalinity	0.810***	−0.746**	0.587***	0.537***	0.521**	1.000									
Dissolved Oxygen	0.343	0.126	−0.013	0.281	0.196	0.356	1.000								
Salinity	0.192	0.070	−0.086	0.134	−0.201	−0.225	−0.096	1.000							
Dissolved Organic Matter	0.308	−0.187	0.045	−0.505**	0.502**	−0.199	−0.031	−0.411**	1.000						
Phosphate-Phosphorus	0.177	0.029	0.161	0.045	0.046	−0.523	−0.226	−0.189	−0.295	1.000					
Nitrate nitrogen	0.492**	0.155	0.161	0.534**	−0.368*	−0.137	0.032	−0.281	0.052	−0.631***	1.000				
Silicate	0.607***	0.132	−0.131	0.285	−0.547**	0.382*	0.408***	−0.604***	0.107	−0.723	0.036	1.000			
Hardness	0.011	0.308	0.455***	0.594**	0.594***	−0.547***	0.547***	0.165	−0.058	−0.460**	−0.095	0.471**	1.000		
Calcium	0.003	0.300	0.036	0.214	0.523**	0.889***	0.592***	0.889***	0.161	0.561***	−0.147	0.353	0.832***	1.000	
Magnesium	−0.280	0.870***	0.715***	0.708***	0.708***	0.839***	0.318	0.178	−0.209	−0.216	−0.227	0.417**	0.858***	0.454**	1.000

*** $P < 0.01$
** $P < 0.05$
* $P < 0.10$

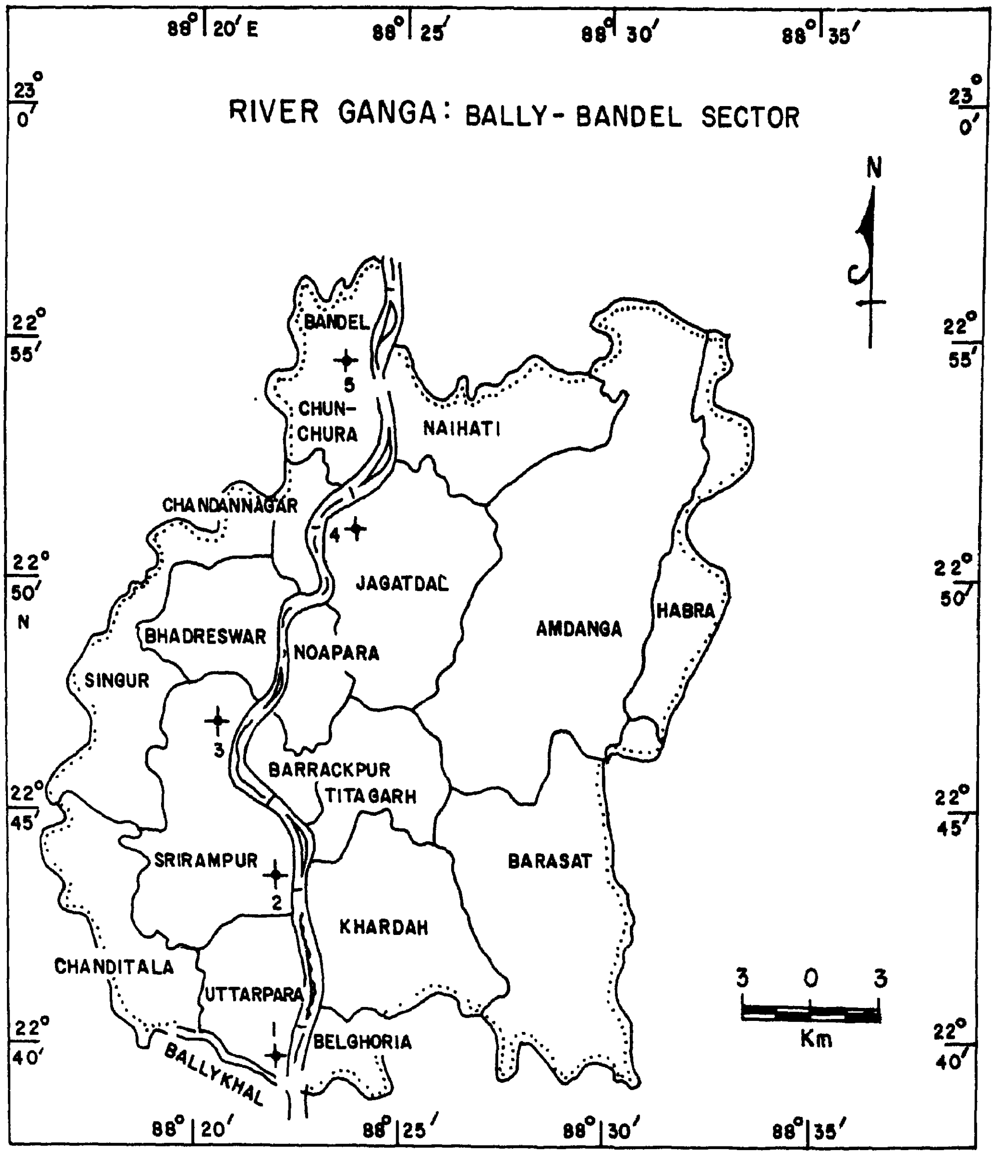

Figure 27.1 : Field Stations : 1 – 5 +

+ indicates two stations one each on Western and Eastern bank

Station – 1 : Bally (Western bank), Dakshineshwar (Eastern bank);
Station – 2 : Rishra (Western bank), Khardha (Eastern bank);
Station – 3 : Sheoraphully (Western bank), Barrackpore (Eastern bank);
Station – 4 : Chandannagar (Western bank), Jagatdal (Eastern bank);
Station – 5 : Bandel (Western bank), Naihati (Eastern bank).

Table 27.2. Water Temperature is found to be significantly correlated with Transparency, *p*H, Total Alkalinity, Nitrate- nitrogen and Silicate.

Transparency : Due to the presence of sand and silt, water was turbid hence transparency was low. In general, Transparency value showed gradual increase from postmonsoon to winter. The higher value of extinction coefficient indicates low penetration of light to lower depths. The lower values of the same from March onwards to October, reflect higher value of Transparency at that time. Transparency was significantly correlated with Specific Conductivity, Total Alkalinity and Magnesium.

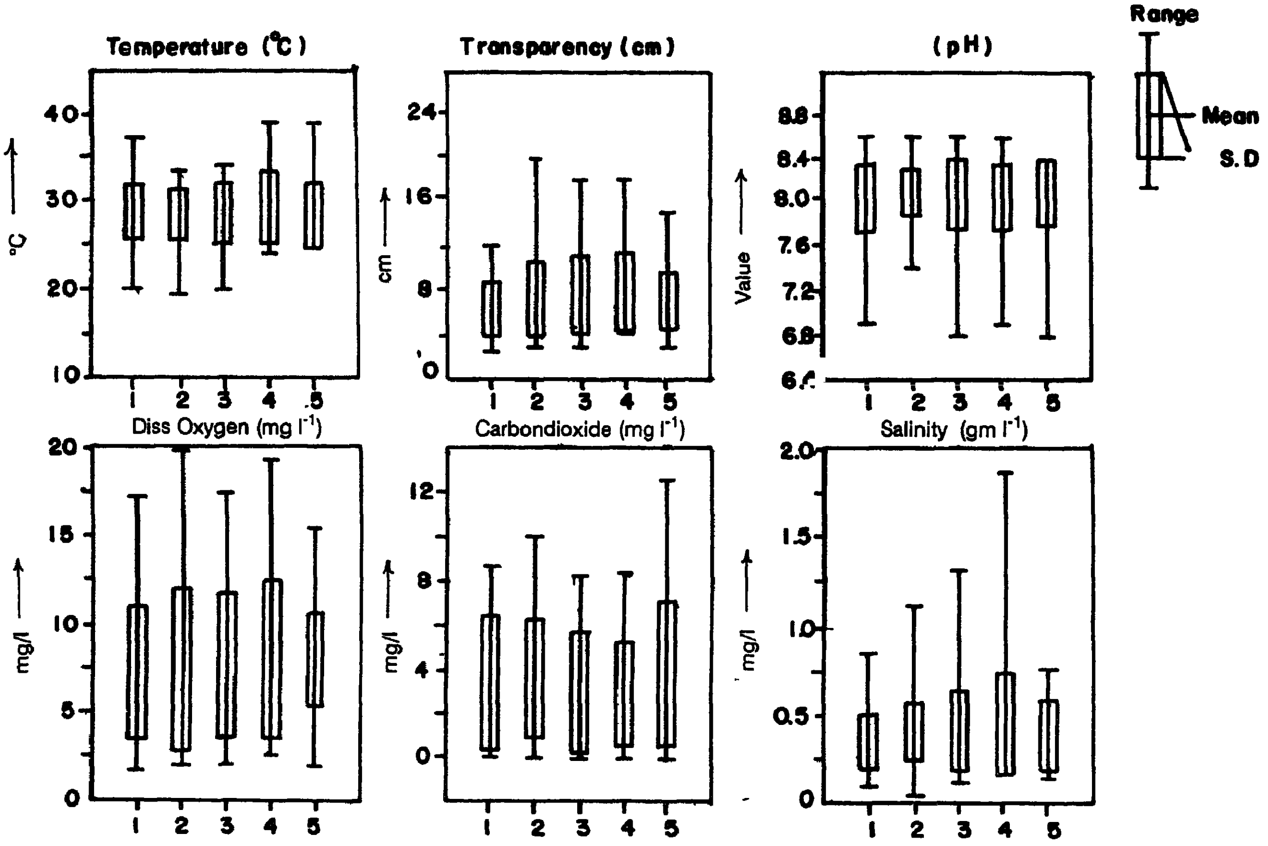

Figure 27.2a : Data Summary of the Abiotic Parameters (Stations : 1 – 5 : X – Axis)

Seasonal fluctuation of *p*H level varied a little. The highest value observed 8.60 and the mean cumulative value 8.08 indicate the alkaline nature of the water. *p*H was significantly correlated with Carbondioxide, total alkalinity, Dissolved organic matter, Hardness, Nitrate nitrogen and Magnesium.

The mean Specific Conductivity value was found to be maximum at Station 1 (X = 409.95 μmhos/cm) presumably due to the frequent inputs from the nearby canal which carries large amounts of salt and other nutrients from adjacent agricultural, industrial as well as domestic effluents. The cumulative value for the entire stretch indicates a decreasing trend during summer (March - June) and the lowest value was observed during winter (October). However, Specific conductivity is less conservative since it is affected by ions other than the chlorides which are biologically active. *p*H, Carbondioxide, Total Alkalinity and Magnesium were significantly correlated with Specific Conductivity.

A relatively higher concentration of Carbondioxide observed may be due to the fact that this essential gas is poorly utilized by phytoplankton, the density of which is too low. Significant correlation was found to exist with Total Alkalinity, Dissolved Organic Matter(DOM), Nitrate-nitrogen, Silicate, Hardness, Calcium and Magnesium.

Fluctuation of cumulative salinity was considerable. However, higher levels were generally noted during winter with declining trends with the onset of summer which may be attributed to the gradual increase in dilution with freshwater discharged from Farraka and other tributaries into the river basin. Besides, frequent tidal action also significanly contributed to the fluctuation of this parameter. DOM, Silicate and Calcium were significantly correlated with Salinity.

Generally low values of hardness were noted during monsoon. Transparency, Specific conductivity, *p*H, Total alkalinity and Nitrate-nitrogen exerted positive correlation with Hardness while with Carbondioxide, and Dissolved organic matter, the relationship was inverse.

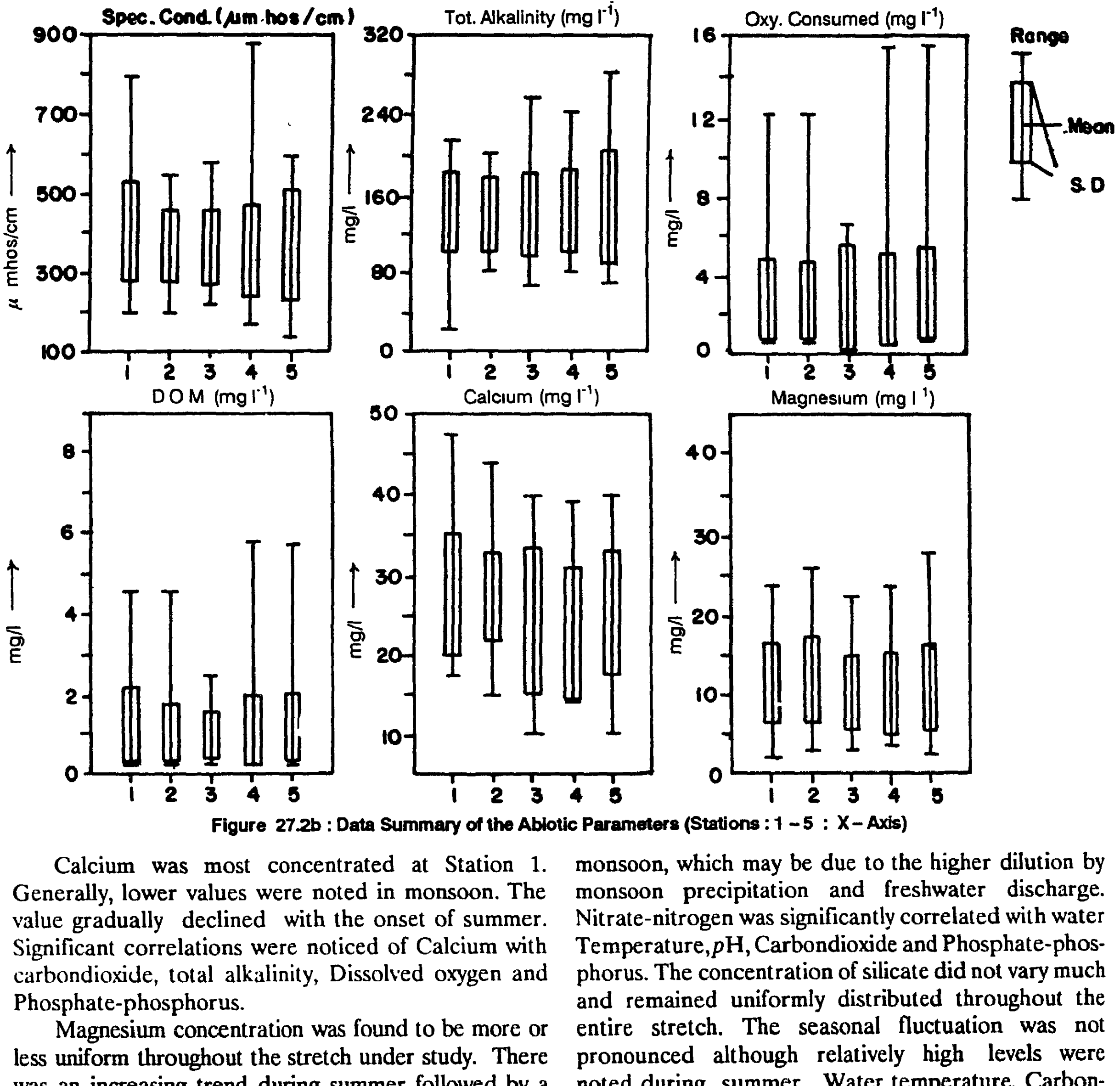

Figure 27.2b : Data Summary of the Abiotic Parameters (Stations : 1 – 5 : X – Axis)

Calcium was most concentrated at Station 1. Generally, lower values were noted in monsoon. The value gradually declined with the onset of summer. Significant correlations were noticed of Calcium with carbondioxide, total alkalinity, Dissolved oxygen and Phosphate-phosphorus.

Magnesium concentration was found to be more or less uniform throughout the stretch under study. There was an increasing trend during summer followed by a trough trend in monsoon. Significant correlation was noted with Transparency, Specific conductivity, *p*H, Carbondioxide, Total Alkalinity and Silicate.

Phosphate-phosphorus is considered to be one of the most important limiting nutrients for the autotrophic organisms. The level of Phosphate-phosphorus was highest at Station 2. The variation of Phosphate-phosphorus was very much irregular and the fluctuation was high. Phosphate-phosphorus was found to be inversely correlated with Carbondioxide.

The cumulative data of Nitrate-nitrogen indicated that the concentration was relatively lower during monsoon, which may be due to the higher dilution by monsoon precipitation and freshwater discharge. Nitrate-nitrogen was significantly correlated with water Temperature, *p*H, Carbondioxide and Phosphate-phosphorus. The concentration of silicate did not vary much and remained uniformly distributed throughout the entire stretch. The seasonal fluctuation was not pronounced although relatively high levels were noted during summer. Water temperature, Carbondioxide, Total Alkalinity, Salinity and Phosphate-phosphorus were found to be significantly correlated with Silicate.

Dissolved Organic Matter constitutes an essential nutritive supplement for the autotrophic organisms and primary consumers as well. These organic compounds are particularly important for periphyton, zooplankton and benthic macroinvertebrates. *p*H, Carbondioxide and Salinity were significantly correlated with Dissolved Organic Matter.

BOD load was high at Station 2 compared to that of Station 5. The load in Station 2 was under permissible

TABLE 27.3

List of Periphyton

Bacillariophyceae	Chlorophyceae	Cyanophyceae	Protozoa	Rotifera	Ostracoda	Others
Amphora sp.	*Ulothrix* sp.	*Oscillatoria* sp.	*Epistylis* sp.	*Conochilus* sp.	*Cypris* sp.	Nematodes
Tabellaria sp.	*Oedogonium* sp.	*Merismopedia* sp.	*Hexotrichas* sp.	*Rotaria* sp.	*Stenocypri* sp.	*Chaetonotus* sp.
Fraglaria sp.	*Characium* sp.	*Anabaena* sp.	*Lionotus* sp.	*Furcularia* sp.		
Coscinodiscus sp.	*Ankistrodesmus* sp.	*Spirulina* sp.	*Stentor* sp.	*Brachionus* sp.		
Stephanodiscus sp.	*Pediastrum* sp.	*Phormidium* sp.	*Loxodes* sp.			
Asterionella sp.	*Stigeoclonium* sp.	*Lyngbya* sp.	*Leucophrys* sp.			
Navicula sp.	*Closterium* sp.		*Lacrymaria* sp.			
Nitzschia sp.	*Chlorococcum* sp.		*Oxytricha* sp.			
Synedra sp.	*Spirogyra* sp.		*Chilodon* sp.			
Diatoma sp.	*Tetraspora* sp.		*Bursaria* sp.			
Melosira sp.	*Rhizoclonium crassipelitum*		*Thursaria* sp.			
Cymbella sp.			*Dileptus* sp.			
Cyclotella sp.	*R. pachydermum*		*Opercularia* sp.			
Gomphonema sp.	*Cladophora* sp.		*Pyxidium* sp.			
Biddulphia sp.	*C. flexuosa*		*Difflugia* sp.			
Chaetoceros sp.	*C. insignis*		*Heterophyrys* sp.			
Pinnularia sp.			*Acanthocystis* sp.			
Pleurosigma sp.						
Gyrosigma sp.						
Frustulia sp.						
Diploneis sp.						
Amphipleura sp.						
Neidium sp.						
Anomoeoneis sp.						
Cocconeis sp.						
Cymatopleura sp.						
Rhizosolenia sp.						
Rhopalodia sp.						

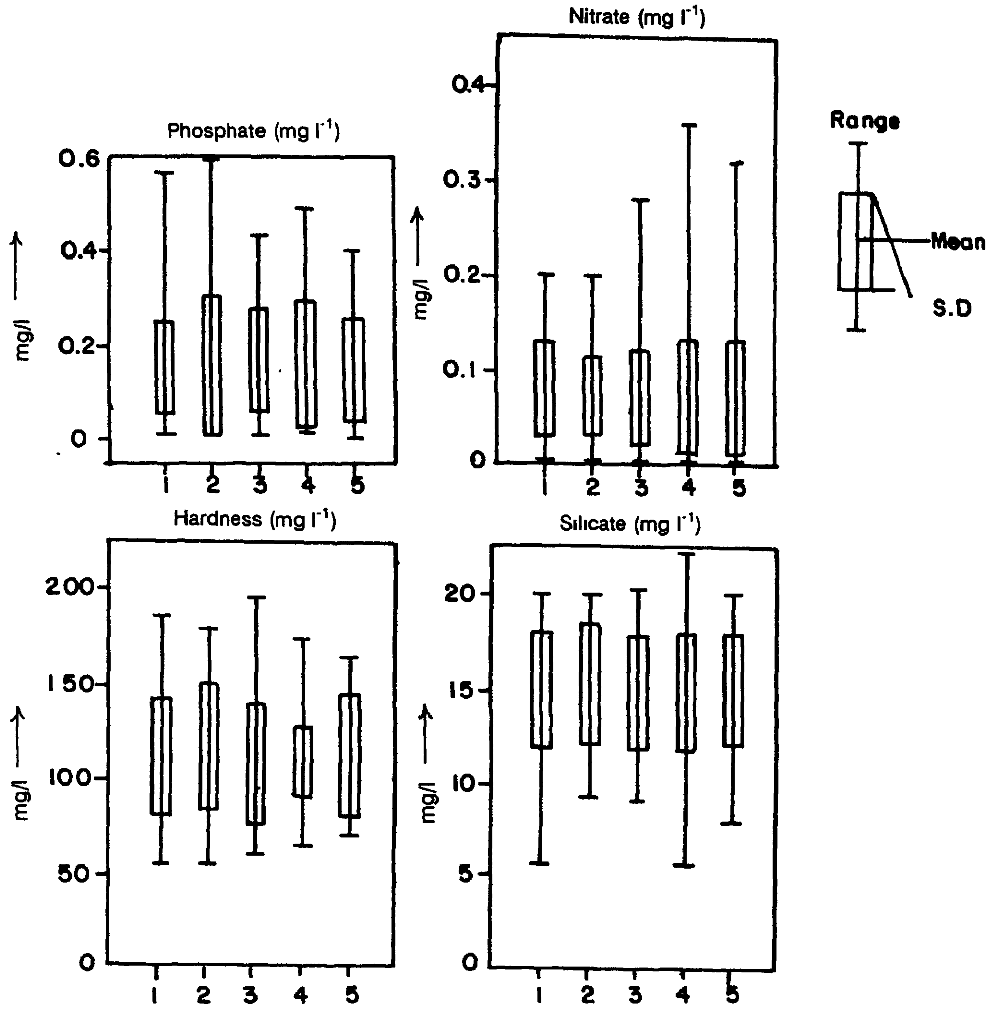

Figure 27.2c : Data Summary of the Abiotic Parameters (Stations : 1 – 5)

limits during monsoon and never exceeded the critical level of 15 mg/l $^{-1}$. The high BOD level at Station 2 was presumably due to maximum number of effluent discharge points situated on either side of the river at this location. The lowering of BOD during monsoon was due to maximum fresh water discharge as well as precipitation and surface run off.

Spots selected for macrophyte collection were – (a) Bally, (b) Rishra, (c) Serampore, (d) Sheoraphully, (e) Baidyabati, (f) Hugly Stationghat, (g) Bandel on the Western bank of the river. On the Eastern bank of the river, the spots selected were – (a) Dakshineswar, (b) Kamarhati, (c) Panihati, (d) Khardah, (e) Barrackpore, (f) Ichapur, (g) Shymanagar, (h) Jagatdal, and (i) Naihati.

The abundance of the following biotic communities was examined:

(a) Periphyton	:	Qualitative
(b) Phytoplankton	:	Qualitative and Quantitative
(c) Macrophytes	:	Qualitative
(d) Zooplankton	:	Qualitative and Quantitative
(e) Macrozoobenthos	:	Qualitative

Data collected were subjected to statistical analysis in order to assess the relative influence of the independent variables on the dependent ones.

Periphyton : Periphytic assemblage was studied only from a qualitive view point. The assemblage was a combination of both microflora and microfauna of

TABLE 27.4

List of Phytoplankton

Chlorophyceae	Cyanophyceae	Euglenophyceae	Bacillariophyceae	Bacillariophyceae
Ulothrix sp.	*Oscillatoria princeps*	*Euglena oxyuris*	*Melosira granulata*	*Amphora* sp.
Oedogonium sp.	*O. proteus*	*Euglena* spp.	*Melosira* spp.	*Cymbella* sp.
Spirogyra spp.	*Oscillatoria* sp.	*Phacus* sp.	*Nitzschia vitrea*	*Gomphonema* sp.
Hydrodictyon reticulatum	*Microcystis aeruginosa*		*N. sigma*	*Gyrosigma* sp.
Cladophora sp.	*M. flos-aquae*		*N. longissima*	*Diatoma* sp.
Pediastrum simplex	*Merismopedia* sp.		*N. seriata*	*Ditylum brightwelli*
Pediastrum sp.	*Anabaena* sp.		*Nitzschia* spp.	*Thallasiosira marginata*
Pediastrum duplex	*Spirulina* sp.		*Coscinodiscus granii*	*Tabellana* sp.
Eudorina elegans	*Lyngbya* sp.		*C. radiatus*	*Lauderia* sp.
Pandorina morum	*Phormidium* sp.		*C. commutatus*	*Diploneis* sp.
Chlorella sp.	*Trichodesmium* sp.		*Coscinodiscus* spp.	*Amphipleura* sp.
Ankistrodesmus sp.			*Stephanodiscus* spp.	*Neidium* sp.
Closterium sp.			*Fragilaria intermedia*	*Anomoeoneis* sp.
Cosmarium sp.			*Synedra* spp.	*Cocconeis* sp.
Zygnema sp.			*Navicula* spp.	*Cymatopleura* sp.
Tetraspora sp.			*Pleurosigma* spp.	*Rhopalodia* sp.
Scenedesmus sp.			*Asterionella japonica*	*Skeletonema costatum*
Kirchneriella sp.			*Biddulphia mobiliensis*	*Lithodesmium* sp.
			B. sinensis	*Hemidiscus* sp.
			Planktoneilla sol	*Rhizosolenia robusta*
			Pleurosigma angulatum	*R. styliformis*
			Pinnularia sp.	*R. alata*
			Chaetoceros sp.	*Rhizosolenia* sp.
			Cyclotella sp.	

TABLE 27.5

List of Macrophytes (Aquatic and Semiaquatic)

Sl.No.	Name	Family	Sl.No.	Name	Family
1.	*Wedelia calendulacea*	Asteraceae	18.	*Phyla nodiflora*	Verbenaceae
2.	*Eclipta alba*	Asteraceae	19.	*Chenopodium indicum*	Chenopodiaceae
3.	*Grangea maderaspatana*	Asteraceae	20.	*Nasturtium indicum*	Brassicaceae
4.	*Blumea lacera*	Asteraceae	21.	*Heliotropium indicum*	Boraginaceae
5.	*Xanthium* sp.	Asteraceae	22.	*Boerhaavia repens*	Nyctaginaceae
6.	*Tridax procumbens*	Asteraceae	23.	*Argemone mexicana*	Papaveraceae
7.	*Veronia cinerea*	Asteraceae	24.	*Mollugo stricta*	Aizoaceae
8.	*Chrozophora plicata*	Euphorbiaceae	25.	*Fimbristylis dichotoma*	Gramineae
9.	*Croton bonpandianum*	Euphorbiaceae	26.	*Paspalum disticum*	Gramineae
10.	*Phyllanthus nirun*	Euphorbiaceae	27.	*Scoparia dulcis*	Scrophulariaceae
11.	*Jatropha gossypifolia*	Euphorbiaceae	28.	*Sida rhombifolia*	Malvaceae
12.	*Rumex dentatus*	Polygonaceae	29.	*Leonurus sibiricus*	Labiatae
13.	*Polygonum* sp.	Polygonaceae	30.	*Eichhornia crassipes*	Pontederiaceae
14.	*Alternanthera sessilis*	Amaranthaceae	31.	*Sagittaria sagittifolia*	Alismataceae
15.	*Amaranthus spinosus*	Amaranthaceae	32.	*Typha* sp.	Typhaceae
16.	*Alternanthera philoxoroides*	Amaranthaceae	33.	*Juncellus* sp.	Cyperaceae
17.	*Lippia nodiflora*	Verbenaceae	34.	*Cyperus* sp.	Cyperaceae

which the former one was found to be dominant. Twenty eight diatom genera, six blue greens, twelve green algae, fifteen ciliates, one rhizopod and two actinopods, four rotifers, two ostracods, nematodes (could not be identified) and *Chaetonotus* from the submerged natural substrates were identified (Table 27.3)

Phytoplankton : Phytoplankton of river Ganga in the stretch under report has been found to be an assemblage of diverse types both fresh and estuarine, mainly dominated by the diatoms followed by blue greens and green algae . The phytoplanktonic abundance has been grouped under four major classes 19 species of Chlorophyceae, 11 of Cyanophyceae, 3 of Euglenophyceae and 50 species of Bacillariophyceae (Table 27.4). The abundance of these groups in different seasons is represented in Figure 27.3.

Aquatic Macrophytes : The plants identified were mainly aquatic and some were semiaquatic in nature. Table 27 5 shows the list of the macrophytes collected. It has been noted that *Eichhornia crassipes* of family Pontederiaceae was common and found to float on the river and noted in almost all the seasons.

Zooplankton . The river zooplankton as studied presently may be categorized in three major taxonomic groups viz., Copepoda Rotifera and Cladocera (Table 27 6) and their seasonal abundance is shown in Table 27.7 The monthly percentage contribution of each group of zooplankton is represented in Figure 27.4. During the study altogether 35 species of Rotifera, 12 of Cladocera and 20 species of Copepoda were recorded.

Numerically, maximum zooplankton (X = 51 units/l) population was recorded at Station-1 while the minimum (X = 32 units/l) was st Station-4. However, the differences in the numerical abundance of zooplankton community at the other stations were narrow.

Rotifer community was found to be represented by the maximum number of species of which genus *Brachionus* is the predominant one.

Copepod fauna is a combination of both estuarine as well as fresh water forms. Altogether twenty six species were identified. The abundance of the cladocerans is very poor both from quantitative as well as qualitative point of view.

Numerically, the copepods outnumbered the other groups at all the stations. Rotifera constituted the next highest followed by the Cladocerans.

The occurrence of Cladocera (*Bosmina, Moina, Diaphanosoma and Ceriodaphnia*) was very much insignificant in 1985, though a little higher value was noted during summer and the peak was observed in April 1986 (19 units/l). In 1987, however, the peak was recorded in September (14 units/l)

TABLE 27.6

List of Zooplankton

Rotifera	Cladocera	Copepoda
Brachionus patuus	*Ceriodaphnia* spp.	*Mesocyclops hyalinus*
B. angularis	*Diaphanosoma excisum*	*M. leuckarti*
B. diversicornis	*Alona rectangula*	*Cyclops fimbriatus*
B. forticula	*Alona pulchella*	*C. prascinus*
B. rubens	*Moina daphnia*	*Oithona similis*
B. caudatus	*Moina micrura*	*O. rigida*
B. calyciflorus	*Moina brachiata*	*O. brevicornis*
B. falcatus	*Bosmina meridionalis*	*Tropodiaptomus orientalis*
B. quadridentata	*Pseudosida* sp.	*Phillodiaptomus blance*
B. plicatilis	*Podon intermedius*	*Pseudodiaptomus aurivilli*
Keratella tropica	*Evadne nordmani*	*P. lobipes*
K. cochlearis	*Evadne spinifera*	*P. annandalei*
Pompholyx sulcata		*P. vinghami*
Filinia opoliensis		*P. serricaudatus*
F. longiseta		*Rhinocalanus cornutus*
F. terminalis		*Paracalanus parvus*
Epiphanes sp.		*Acartia spinicauda*
Lecane luna		*A. erythraea*
Philodina sp.		*A. centura*
Rotaria sp.		*A. negligens*
Rotaria neptuna		*Acartiella sewelli*
Hexarthra mira		*Oncea* sp.
Polyarthra multiappendiculata		*Microsetella rosea*
Cephalodella forficula		*Macrosetella gracilis*
C. gibba		*Heliodiaptomus cinctus*
C megalocephala		*Laophonte bengalensis*
Eospora anthades		
Trichocera cylindrica		
Asplanchna brightwelli		
A. priodonta		
A. intermedia		
Lepadella patella		
Tripleuchlanis plicata		
Platius quadricornis		
Anuraeopsis coelata		

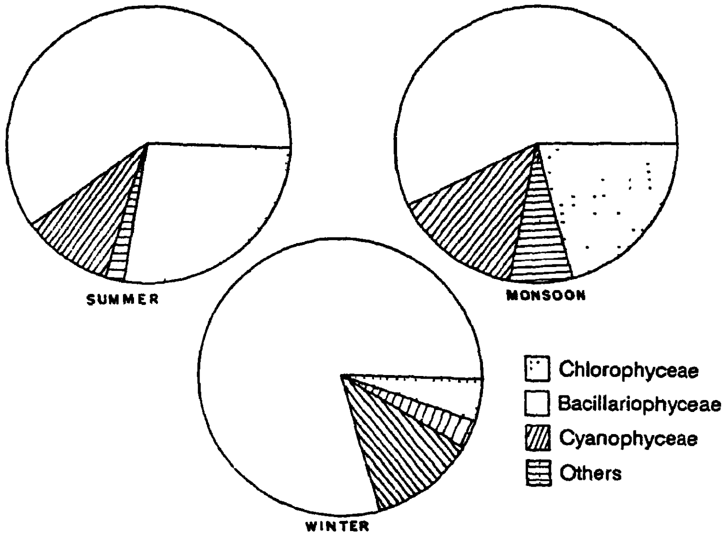

Figure 27.3 : Percentage Abundance of three Dominant Phytoplanktonic Groups

Macrozoobenthos : Macrozoobenthic organisms were collected from the intertidal zones. Polychaetes were found to be common, though from qualitative view point they are poor. *Capitella capitata, Nepthys oligobranchia, Nereis* spp. and *Prionospio cirrifera* were common. *Eriopisa* spp. and *Idunella* sp. of Amphipoda were also occasionally found in the samples.

Among molluscs, gastropods were found to be common in Stations 2 and 5 and the most abundant genera were *Assimminea* sp., *Hydrobia* sp., *Planorbis* sp., and *Viviparus bengalensis.*

Periphyton : The importance of periphyton in flowing streams has long been envisaged. In fast flowing streams with little sediment for the roots of macrophytes, periphyton may be the only form of autochthonous production (Mann, 1975). The direct measurement of periphyton production is extremely difficult and most estimates are arrived at indirectly which is being derived from rates of colonization on artificial substrates. It is interesting to mention here that at station 1 and 4, *Rhizoclonium crassipelitum* West and West (Family Cladophoraceae) was recorded and probably it is the first record of its habitat from West Bengal. The species is found to be firmly attached (periphytic) to the submerged substratum. Two protozoans viz. *Opercularis* sp. and *Pyxidium* sp. were noticed in association with *R. crassipelitum* and *R. pachydermum*. Among other Cladophorales, *Cladophora flexuosa* and *C. insignis* were also found to be present in almost all the sampling stations. There is no doubt that the potential for periphyton in running water is very high.

Phytoplankton : Phytoplankton community is of immense importance as primary producers. Due to the frequent tidal action, the floristic composition of the stretch under study comprises both the estuarine and the freshwater forms. It has been noted that the phytoplankton community is mainly dominated by the diatom flora and claims always more than 60% of the total in all the seasons followed by Chlorophyceae and Cyanophyceae.

The pattern of seasonal variation of phytoplankton exhibits that Chlorophyceae was generally maximum during summer and least in winter while, the Cyanophyceae or the blue greens were present in monsoon only. However, the diatom flora are found to be maximum in all the months. In the stretch under study due to immense turbidity the production of phytoplankton was very poor.

Aquatic Macrophytes : Altogether 34 aquatic macrophytes were identified (Table 27.5). The semiaquatic species were restricted to the regions where maximum siltation was observed. Among the floating ones *Eichhornia crassipes* was found almost throughout the year and sometimes found in larger concentrations at the site of the sewage outfalls.

Zooplankton : The abundance of zooplanktonic community was studied in detail than those of the others. Copepods constitute the major part of the biota. It is explicit that except for few months copepod appears always more than 50 % of the total. It is needless to mention that the nauplii of the copepod fauna lead this

TABLE 27.7

Seasonal Abundance of Zooplankton Groups (units/l)

Year/Season	Rotifera	Copepoda	Cladocera
1985			
Summer	9	42	1
Monsoon	3	19	2
Post Monsoon	7	19	3
Winter	6	12	2
1986			
Summer	17	25	3
Monsoon	5	19	2
Post Monsoon	7	28	3
Winter	6	16	1
1987			
Summer	6	53	3
Monsoon	5	38	3
Post Monsoon	15	62	13

Summer : March–May
Monsoon : June – August
Post Monsoon : September–October
Winter : November–February

group always in highest rank from quantitative viewpoint. The next dominating group was the rotifers. Rotifers are qualitatively large and it is evident that genus *Brachionus* was always the predominant one. Cladocerans were few, though found in appreciable numbers during post monsoon to winter. It is revealed from the study that the abundance of cladocerans, rotifers and copepods in river water appeared in a ratio of 1 : 4 : 15.

In order to assess the importance of abiotic interaction, an attempt was made to analyse the data statistically as shown in Table 27.8. Water temperature showed positive correlation with total zooplankton and an inverse correlation with Transparency, Dissolved Oxygen and BOD.

Total copepod abundance has been found to be significantly correlated with Water Temperature, Transparency and Dissolved Oxygen. However, the relationship is inverse with Dissolved Oxygen. The influence of BOD though inverse was not significant.

TABLE 27.8

Simple Correlation between the total Zooplankton and their Major Groups with the Abiotic Parameters

Parameters	Total Zooplankton	Total Copepoda	Total Cladocera	Total Rotifera
Water temperature (° C)	0.498 **	0.449 **	0.367 *	0.041
Transparency (cm)	−0.378 **	0.573 ***	−0.090 **	0.497 **
Specific Conductivity (μmhos/cm)	−0.128	0.063	−0.303	0.139
*p*H	0.013	−0.002	−0.098	0.148
Free Carbondioxide (mg l^{-1})	−0.093	−0.135	−0.086	0.581 ***
Total Alkalinity (mg l^{-1})	0.002	−0.080	−0.099	0.698 ***
Dissolved Oxygen (mg l^{-1})	−0.650 ***	−0.675 ***	−0.575 ***	−0.283
Salinity (mg l^{-1})	−0.268	0.184	0.442 **	−0.074
Dissolved Organic Matter (mg l^{-1})	−0.015	−0.011	−0.245	0.073
Phosphate-phosphorus (mg l^{-1})	−0.158	−0.097	−0.135	−0.441 **
Nitrate-nitrogen (mg l^{-1})	−0.218	−0.311	−0.429 **	−0.501 **
Silicate (mg l^{-1})	−0.324	−0.245	−0.389 *	−0.537 ***
Hardness (mg l^{-1})	−0.077	−0.134	−0.423 **	0.544 ***
Calcium (mg l^{-1})	−0.234	−0.283	−0.291	−0.858 ***
Magnesium (mg l^{-1})	0.132	0.055	−0.060	0.372 *
Biochemical Oxygen Demand (mg l^{-1})	−0.423 *	−0.271	−0.118	−0.734 ***

*** $P < 0.01$; ** $P < 0.05$; * $P < 0.1$

TABLE 27.9

List of Benthic Macroinvertebrates

Oligochaeta	Polychaeta	Amphipoda	Mollusca	Others
Tubifix sp.	*Capitella capitata*	*Eriopisa chilkensis*	*Viviparus bengalensis*	Chironomid larvae
Der spp.	*Ceratoneris* sp.	*Indunella chilkensis*	*Assiminia* sp.	*Polypedium* sp.
Limnodrilus spp.	*Dendronereis* spp.	*Quadrivisio* sp.	*Hydrobia* sp.	*Stenocypris* sp.
Aulodrilus sp.	*Nepthys oligobranchiata*		*Planorbis* sp.	Decapod juveniles
Branchiura sowerbyi	*Nereis* spp.		*Lymnaea* spp.	
	Prionospio cirrifera		*Amnicola* sp.	
	Prionospio sp.			

A number of parameters have been found to be significantly correlated with total Cladocera and total Rotifera. Temperature, Dissolved Oxygen, Salinity, Nitrate-nitrogen, Silicate and Hardness have been found to exert significant correlation on cladoceran community, of which, the relationship is positive with Temperature and Salinity.

The abundance of rotifer community is found to be highly significant with free Carbondioxide, Total-Alkalinity, Silicate, Hardness, Calcium and BOD followed by transparency, Phosphate-phosphorus, and Nitrate-nitrogen and Magnesium.

The abundance of total zooplanktonic community has a definite seasonal pattern. Not distinctly bimodal but in general, higher abundance was noted during summer, in particular, and post monsoon.

About 250 industrial establishments on either side of the Hugly river producing jute, textiles, pulp and paper, tannery products, chemicals, food, breweries, paints, tyres, thermal power projects, etc. discharge their wastes of different kinds, which directly or indirectly affect the biotic components present therein. It has been observed that BOD exert inverse impact on the zooplankton abundance. The plankton population is adversely affected hence the biological equilibrium is greatly disturbed.

Benthic Macroinvertebrates : The estuarine polychaetes dominate over others. It may be pointed out here that among polychaetes the presence of *Capitella capitata* is found principally around the sewage discharge points in large numbers. The next dominating macroinvertebrates was the molluscs. Oligochaetes were very few both qualitatively and quantitatively though these were fairly in good concentration at Station 5 (Table 27.9).

On the basis of the qualitative study of Benthic Macroinvertebrates the stretch under study may be categorized as Oligohaline Zone which is also supplemented by the salinity studies.

Polychaetes were found to be represented by 7 dominant species of which, *Capitella capitata, Nereis* spp., *Ceratoneries* sp. and *Dendronereis* sp. were very common. Among the molluscs post winter dominance of *Assiminia* sp., *Planorbis* sp. and *Hydrobia* sp. was remarkable especially at Station 5. However, *Viviparus bengalensis* was very common during post monsoon in almost all the stations under study.

Amphipods were rarely present but *Eriopisa chilkensis* was found to be abundant at Stations 1 and 2 specially during summer and monsoon.

Among others, juveniles of crab were encountered in large numbers during monsoon and post monsoon. Chironomid larvae were found in small numbers and were principally restricted at the sewage discharge points.

Significant Findings

ABIOTIC PARAMETERS

(a) Transparency always showed minimum values indicating the high turbidity of water.

(b) Extinction coefficient value, otherwise known as photosynthetically active radiation in water, was also low.

(c) *p*H of water was inclined towards the alkaline side.

(d) High alkalinity value indicated that water was nutrient enriched and was of the hard type.

(e) Free CO_2, when present was moderately high indicating poor water quality.

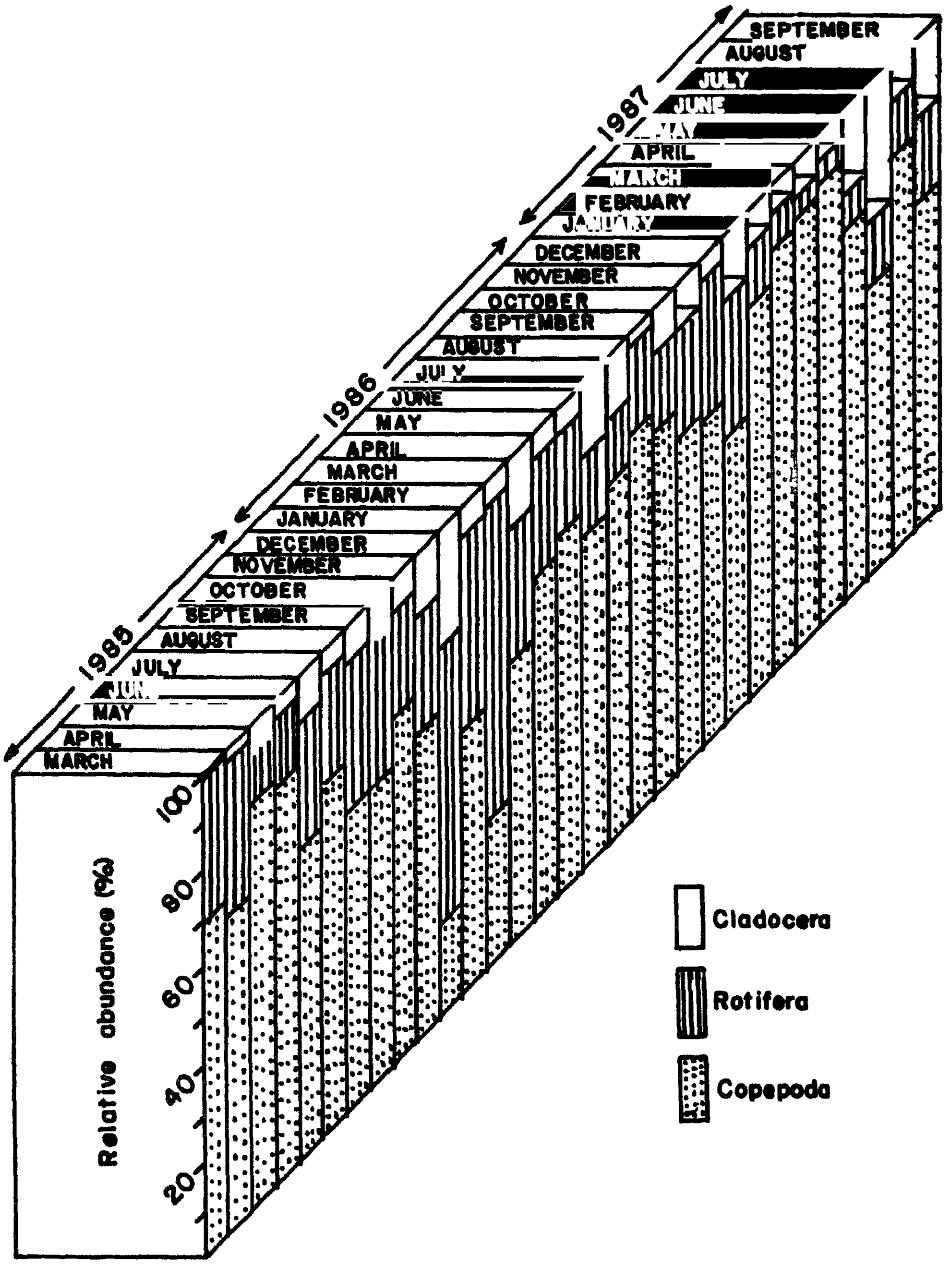

Figure. 27.4 : Monthly Variations of Zooplankton

(f) Dissolved Oxygen was always present in appreciable quantity probably due to the high current and mixing from the atmosphere rather than autotrophic production

(g) Salinity was low due to higher rates of freshwater discharge.

(h) Dissolved Organic Matter (DOM) concentration was very low.

(i) Nutrients (phosphate, nitrate and silicate) were found in appreciable concentrations possibly due to surface run off from riparian areas and discharge from tributaries and municipalities.

(j) BOD level never reached the critical value, although there were many effluent discharge points. Due to strong water current the BOD presumably got adequately diluted within a short time.

Biotic Parameters

- (a) Co-existence of fresh and estuarine organisms.
- (b) Low density and diversity of the planktonic as well as benthic forms indicating the presence of some stress.
- (c) Phytoplankton was dominated by Bacillariophyceae followed by Cyanophyceae and Chlorophyceae.
- (d) *Rhizoclonium crassipelitum* of Family Cladophoraceae of green algae was recorded and probably the first record from West Bengal.
- (e) Periphytic assemblage was found to be a combination of both microflora and fauna. Bacillariophyceae, the diatoms constituted the major community.
- (f) Macrophytes along the bank (submerged form) and truly aquatic forms were diverse.
- (g) Following twenty six Bioindicator species were identified.

Phytoplankton

BACILLARIOPHYCEAE

Melosira granulata
Coscinodiscus granii
Stephanodiscus sp.
Synedra ulna
Navicula sp.
Diatoma sp.

CYANOPHYCEAE

Microcystis aeruginosa
Spirulina sp.
Oscillatoria princeps

Zooplankton

COPEPODA

Mesocyclops sp.
Pseudodiaptomus sp.

ROTIFERA

Brachionus calyciflorus
Brachionus angularis
Brachionus plicatilis
Rotaria neptuna
Keratella tropica
Asplanchna brightwelli
Asplanchna priodonta

Benthic Macroinvertebrates

POLYCHAETA

Capitella capitata
Ceratoneris sp.
Prionospio cirrifera

OLIGOCHAETA

Tubifex sp.
Aulodrilus sp.
Branchiura sowerbyi

MOLLUSCA

Viviparus bengalensis

INSECT LARVA

Chironomus spp.

Remedial Measures and Recommendations

Following remedial measures and recommendations are suggested to restore and maintain the biological health of the stretch of the River Ganga.

1. An inventory of aquatic flora and fauna should be made and preserved through information retrieval system.
2. Siltation is one of the major problems of the river. In some areas the river bed is so raised (Dakshineswar, Naihati and Bandel) that in years to come the river itself may cease to exist. Therefore, more water flow is needed, which will (i) save Ganga from being moribund, (ii) lower the existing BOD load and (iii) reduce salinity level.
3. Soil erosion accompanied by surface runoff increases the turbidity of the river which adversely affect its ecological health. Therefore, suitable plantations at proper places on the riparian land may be encouraged and practised. This will reduce erosion resulting in an increase of water transparency.
4. Dredging operation should be initiated immediately as an emergency measure at the places where it is most needed.
5. Diversion of sewage and industrial discharge points should be made immediately. If this is not possible proper treatment plants should be installed so as to make the quality of effluents within permissible limits. (It is gratifying to note that attempts in this direction are already made).
6. Indiscriminate diversion of Ganga water through irrigation canal system should be discouraged. If it is at all necessary, proper environmental impact analysis from holistic point of view should be made before such attempts.
7. Inland water transport should not be allowed to disturb the biological health of the river through oil spill.

8. Indiscriminte fishing of the juveniles, especially *Hilsa ilisha* should not be allowed to continue.
9. No serious attempts have so far been made to control and prevent the river pollution by legal and administrative means.

   Steps should be taken to bring scientists, policy makers, planners and competent legal authorities to deliberate and devise ways for proper legislative measures. If required, punitive measures should be recommended.
10. Studies on benthic macroinvertebrates and periphyton should be taken up.
11. A long term surveillance programme should be initiated.
12. A systesm approach to water management of the river Ganga should be made.

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28

Some Aspects of the Biogeography of the Ganga

T. M. DAS*

The Ganga basin is by far the largest in India, with a geographical area of 8,61,404 sq km within the country.

As compared to the river Nile (6,650 km) or Amazon (6,500 km) the total length of the Ganga is only 2,525 kms but it carries the highest quantity of sediment, (2.4 billion metric tons per year) which is greater than that carried by any other river of the world. The Ganga has also acquired a unique position among other mighty rivers of the world by possessing the largest delta which was formed with deposition of these sediments through the ages. And it is these sediments that keep enlarging the delta and extending it in the direction of the sea.

The enormous sediment load of the Ganga may be attributed to the following factors: (1) The Himalayas, the birth place of Ganga, is comparatively young in age, mostly made up of ever unstable rocks with high erosion rate (2) The size of the drainage basin is enormous with steep angle of elevation in the Himalayan region. (3) There are numerous mighty tributaries flowing through the basin and by their joint combing action soils from all over the basin are transported to the main stream. (4) Most part of the basin is thickly populated. Intense agricultural practices are being followed through ages and the forest area is greatly reduced, the natural contrivances for restraining soil erosion are almost nonexistent in those agricultural belts. This situation is further aggravated by the digging of numerous irrigation canals in Uttar Pradesh and Bihar. About one crore thirty lakh hectares of agricultural land are irrigated from the water of the Ganga and its tributaries. Such irrigation water, in turn, makes the soil vulnerable to erosion. Every year about 1,15,000 tonnes of precious fertilizers are washed away with the agricultural waste water and find their way into the Ganga, of which nitrogen is 88,600 tonnes, phosphorus 17,000 tonnes and potassium 9,200 tonnes. The water holding capacity of the Ganga and its tributaries has been reducing due to the high rate of siltation, resulting in devastating floods at regular intervals during the current century.

Population Distribution

The Ganga basin is the home of nearly 37 per cent of the total population of the country. About 84 per cent of the people live in rural areas, whereas 16 per cent, as much as 40 millions are distributed over 692 towns and cities of the basin. The overall density of population is 297 persons to a sq km compared to 196 for the whole of India. The variation of density of population in different parts of the basin is spectacular. The density of urban population is at least 20-40 times more than that of rural population. The highest density of rural population is found in the lower Gangetic plains, e.g., in West Bengal with 466 persons to a sq km. It has increased to 20,000 to a sq km in the industrial belts of Hugli and 24 Parganas in West Bengal. The rural density falls off as one goes upstream, with Uttar Pradesh 286 persons, and Himachal Pradesh 69 persons to a sq km.

There are 692 towns and cities distributed over the eight Gangetic states. Majority of the towns have a population of less than 100,000, yet there are 62 large cities having more than 100,000 persons each, they jointly represent about 60 per cent of the total urban population in the basin.

The growth rate of population in the Gangetic basin is very high. During the span of forty years (1941–1981), the total population has doubled which is the root cause of numerous unresolved problems in this vast region.

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* The data on medicinal plants in Rishikesh-Haridwar is taken from an independent report prepared for the working group by Prof V. Shankar of Gurukula Kangri Vishwavidyalaya, Haridwar.

Economic Condition of the Population

About 80 per cent population in the basin are farmers and farm labourers, they solely depend on agriculture for their subsistence. Most of them are small, farmers; the number of landless farm labourers is also increasing. Majority of the people in the basin are poor and live near poverty line, the number of poor people is also increasing at an alarming rate. After independence the industrial development in the basin has steadily been increasing. Taking the index of industrial production of the year 1970 as 100, in 1985 it was nearly 200, the average annual increase is thus over 6 per cent. But such spectacular increase of industrial production did not create any favourable impact on the general poverty level.

Illiteracy among the common people is also very high (about two third of the population). Illiteracy among the women folk and among the farmers and farm labourers is alarmingly high.

Land Use Pattern

The Ganga basin is extensively cultivated. Some 509,994 sq km of land, which constitute 62.45 per cent of the total reporting area of the basin, have been categorized as cultivable. Non-arable land in the Ganga basin covers an area of 189,646 sq km which constitute some 23.2 per cent of the total reporting area of the basin. This category of land comprises such tracts which cannot be put to agricultural or silvicultural uses because of its unproductive character. It also includes other types of lands e.g., human settlements, industrial structures, roads, railways, airports, etc. Over 5 per cent of the geographical area of the basin is used for construction of human habitation alone.

In the Ganga basin the net sown area constitutes some 52.41 per cent. The gross sown area turns out to be 130 per cent of the net sown area which indicates that a substantial portion of the net sown area is under double cropping. In some isolated areas of intensive farming a small percentage of tract is also put to triple cropping, and interculture of several crops together.

To the soil of Ganga basin, a huge quantity of fertilizers, insecticides and pesticides are continuosly being added, especially during the last two decades of Green Revolution. About 1.15 million tonnes of chemical fertilizers comprising nitrogen 77 per cent, phosphorus 15 per cent, and potassium 8 per cent were applied to the agricultural fields of Ganga basin in 1976-77 alone, which represented as much as 33.8 per cent of India's total annual consumption of 3.14 million tonnes. About 2, 600 tonnes of pesticides of different types also were used in the Ganga basin during the year 1976-77.

On account of high intensity of cultivation in the rural sectors and high concentration of people and factories in towns and cities, a huge amount of organic and inorganic pollutants are being generated in the basin, major portion of which eventually find its way into the aquatic system. In the rural sectors the total generation of BOD is of the order of 4.9 million kg per day, but the load is distributed over much larger areas and over larger population. Taking the basin as a whole the average amount of BOD load comes to 24 grams per person per day in the rural sector, in the urban sectors it is as high as 64 grams per person per day. The total generation of BOD in the urban sectors of the basin is around 2.5 million kg per day, of which 53 per cent comes from Uttar Pradesh (1.3 million kg/day), far more than any other states in the basin. West Bengal and Delhi generate urban BOD to the tune of 0.4 and 0.2 million kg per day, respectively.

Land Under Forest

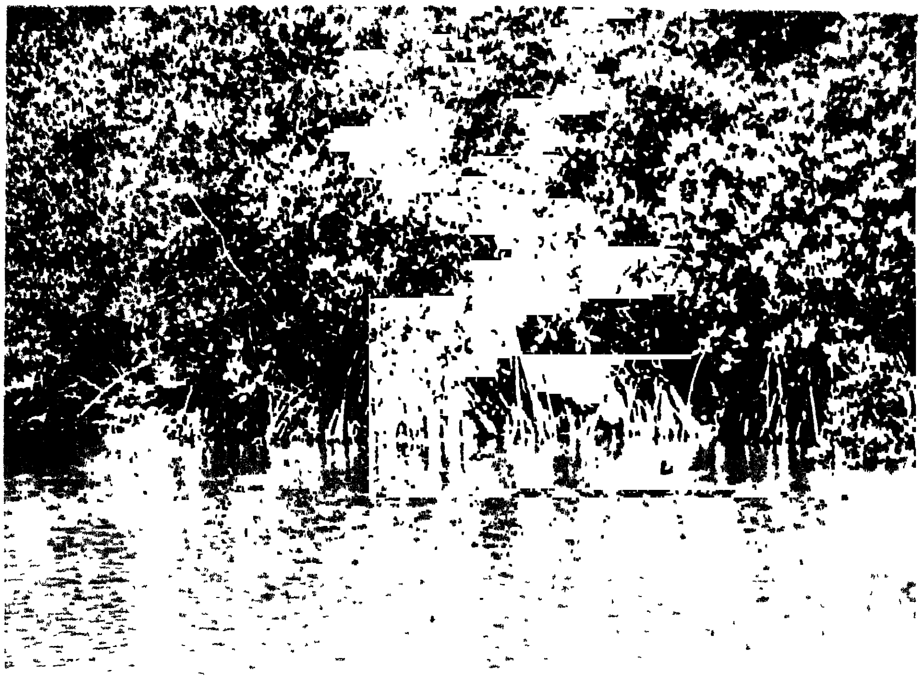
Hardly 14.3 per cent of the total basin is under forest cover. At the national level it may be mentioned that about 20 per cent of land is forested. Most of the forest land in the basin are severely degraded on account of over exploitation. Immediate precautionary measures are called for to check such degradation.

The Gangetic Delta

The Gangetic delta invites our special attention due to its unique position in geography. It is the largest river delta of the world with rich mangrove forests containing very rare and valuable species of plants and animals unparalleled among forest ecosystems.

The Gangetic delta extends for about 400 km from north to south and about 320 km from east to west. During the period of 12th to 16th centuries, the entire Bengal basin suffered a Neotectonic movement, the earth's crust slowly tilted towards the east, as a result most of the water of the Ganga which once had been flowing through the course of Bhagirathi and Bidyadhari of West Bengal gradually shifted to the river Padma of Bangladesh. In West Bengal many former river channels have become clogged with mud and have ultimately become extinct, Bidyadhari being one such. The Hugli river is gradually becoming inactive. Due to reduction of flow of sweet water from the upper stretch, the salinity of the river has greatly increased, which adversely affects the flora and fauna of the Indian mangrove forest. There is a large scale extinction of *Sundari* trees (*Heritiera fomes*) from which the name of Sundarban was derived. During the course of the last two centuries the Javan rhino, water buffalo, swamp deer and gharial have totally disappeared from the Indian Sundarban. (Plate 4 a & b)

PLATE 4 (a)



A Typical Scene of Tidal Forest Sundarban with Mangrove Species *Nipa fruticans*

PLATE 4 (b)

A Typical Scene of Tidal Forest Sundarban with Mangrove Plant Species

TABLE 28.1

True Mangrove Species of the Sundarbans Delta

Family and Species	Habit	Habitat	Frequency	Economic uses
Acanthus ilicifolius L.	Shrub	Mud flat	Common	Soil binder
Nipa fruticans Wurmb.	Tree	River banks	Rare	Leaves for Thatching huts
Phoenix paludosa Roxb.	Shrub	River flats	Common	Pillaring huts
Avicennia alba B1.	Tree	River slopes	Common	Timber and fuel
Avicennia marina (For.) Vierh.	Tree	River slopes	Occasional	Timber and fuel
Avicennia officinalis L.	Tree	River slopes	Common	Timber and fuel
Lumnitzera racemosa Wild.	Tree	River banks	Occasional	Timber and fuel
Excoecaria agallocha L.	Tree	All habitats	Common	Timber and fuel
Excoecaria bicolor Muell.	Tree	River slopes	Occasional	Timber and fuel
Cynometra ramiflora L.	Tree	River slopes	Common	Timber and fuel
Derris scandens Benth.	Shrub	River flats	Common	Soil binder and fish poison
Derris trifoliata Lour.	Shrub	River flats	Common	Soil binder and fish poison
Derris umbellatum DC.	Shrub	River flats	Common	Soil binder and fish poison
Hibiscus tortussus Wall.	Tree	River banks	Common	Timber and fuel
Thespesia lampus (Cav.) Dalz.& Gibs.	Tree	River banks	Occasional	Fuel
Amoora cucullata Roxb.	Tree	Swamp forests	Occasional	Timber and fuel
Xylocarpus granatum Koenig.	Tree	Tidal forests	Occasional	Timber and fuel
Xylocarpus mulucensis (L) Roem	Tree	Tidal forests	Common	Timber and fuel
Aegiceras corniculatum (L) Blanco	Shrub	Swamp forests	Common	Honey and fuel
Aegialitis rotundifolia Roxb.	Shrub	Tidal zone	Occasional	Fuel and source of honey
Porteresia coarctata (Roxb.) Takeoka	Grass	River beds	Common	Fodder and forage
Bruguiera cylindrica B1.	Tree	Tidal forests	Common	Timber and forage
Bruguiera gymnorhiza (L.) Lam.	Tree	Tidal forests	Common	Timber and fuel
Bruguiera parviflora W. & A.	Tree	Tidal forests	Common	Timber and fuel
Bruguiera sexangula (Lour.) Poir	Tree	Tidal forests	Common	Timber and fuel
Ceriope decandra (Griff.) Ding Hou.	Shrub	Tidal forests	Common	Timber and fuel
Ceriops tagal (Perr.) Robins	Shrub	Tidal forests	Common	Timber, tannin and fuel
Kandelia candel (L.) Druce	Shrub	Tidal forests	Common	Timber, tannin and fuel
Rhizophora apiculata B1.	Tree	Tidal forests	Common	Timber, tannin and fuel
Rhizophora mucronata Lam.	Tree	Tital forests	Common	Timber, tannin and fuel
Sonneratia apetala Ham	Tree	Tidal forests	Common	Timber and fuel
Sonneratia caseolaris (L.) Engl.	Tree	Tidal forests	Common	Timber and fuel
Heritiera fomes Buch. Ham.	Tree	Tidal zones	Occasional	Timber
Heritiera littoralis Dry.	Tree	OutsideTidal zones	Occasional	Timber
Brownlowia lanceolata Roxb.	Tree	Tidal forests	Occasional	Timber and fuel

Before the partition the total mangrove forest area of Sundarban covering the southern part of the delta was over 10,000 sq kms, after partition more than 6,000 sq km. has gone to Bangladesh and less than 4,000 sq km remain in West Bengal, in which the Tiger reserve area is over 2, 585 sq km The core area of the reserve is 1,330 sq km which is largely protected as a National Park and no exploitation is allowed. The ecosystem of the Sundarban is very unstable; devastating floods and cyclones are quite frequent, everyday a part of the forest floor is washed with tidal water, for which it is also called tidal forest or littoral forest. The productivity of the mangrove ecosystem is extremely high, it is 27 tonnes/ ha, whereas the productivity of terrestrial ecosystem is 15 tonnes/ha and that of marine ecosystem is only 4 tonnes/ha.

Among various mangrove plant species, the following are common in Sundarban: *Rhizophora conjugata* (Vora), *Rhizophora mucronata, Ceriops roxburghiana* (Garan), *Heritiera fomes* (Sundari), *Avecinia officinalis* (Bine), *Sonneratia apetala* (Keora), *Phoenix paludosa* (Hental), *Nipa fruticans* (Golpata), etc. (Table 28.1). Most of these plant species possess various adaptive mechanisms to thrive in saline habitat. Among the animals the fidler crab is the most abundant, its total biomass is about 7 times higher than that of chital deer in Sundarban. Among other animal species hermit crab, king crab, marine turtle, water monitor, estuarine crocodile, open bill stork, wild pig, different kinds of fish, tiger, wild cat and rock bee (*Apis dorsata*) are quite common in Sundarban.

The main livelihood of the people who live around the Sundarban are fishing, collection of honey, wax and leaf of *Nipa fruticans* from interior of the forest and cultivation of a few salt tolerant crops. Most of the people live below poverty line. Drinking water problem is very acute, people have to move long distances to collect drinking water, purity of which is not always guaranteed.

The main crisis of the Gangetic delta is due to the 3 to 4 folds increase of human population during the last 40 years. Heavy influx of population from Bangladesh is a continuous problem. Per capita resources are rapidly falling. On the other hand, the productivity of soil (agricultural crops) has substantially reduced due to increase of salinity and mismanagement of land. In this part of the Ganga basin, both man and animal have to wage a relentless war for their very existence.

A list of true mangrove plant species of Sunderban delta with their habit, habitat, frequency and economic uses is given in Table 28.1.

Medicinal Plants of Marginal and Riparian Land

The marginal and riparian land of the Ganga is comprised of a large number of plant species which are of ecological and economic importance. They play an important role in nutrient and water conservation and in checking soil erosion. A great many of these plant species possess important medicinal properties and provide a rich harvest for valuable drugs and medicine.

The occurrence and distribution of medicinal plants along the course of the Ganga were studied from three Centres. One is in the upper stretch, from Rishikesh to Garhmukteshwar and the other in the middle stretch, from Mirzapur to Ballia and the third from Munger to Farakka. With occasional exceptions, majority of the common medicinal plants are found to occur from Haridwar, U.P. to Diamond Harbour, West Bengal. Their distribution, however, greatly changes at high altitude above Haridwar and also at the saline, estuarine tract of the Gangetic delta where they are mostly replaced by more adaptive plant species.

Medicinal, nutritive and antipollutant properties of common aquatic plants of the Ganga were studied at the Banaras Hindu University. Gram positive bacteria were found very sensitive against the petroleum ether extract of *Vallisnaria spiralis*, methanol extract of *Hydrocotyle asiatica, Potamogeton crispus*, and *Hydrilla verticellata*. The antipollutant effect of *Eichhornia crassipes, Ipomea aquatica, Hydrilla verticillata*, and *Pistia stratiotes* has been studied with reference to the absorption of nitrate and phosphate from the polluted water. A significant increase of uptake of above chemicals was noted by all the aforesaid plant species.

The Ganga-Shiwalik region is reputed to be a treasure house of drugs. It provides approximately 450 different items of medicine. A list of more important medicinal plants is given in Table 28.2. Since most of the people in a radius of 10 km from Haridwar have a good working knowledge of the medicinal plants, a number of them set up business for collection and sale of medicinal herbs. The annual purchase of medicinal herbs by big pharmacies ranges from Rs. 1.5 lacs to Rs. 2 lacs. The increasing demand of medicinal herbs by pharmacies has led to their over exploitation resulting in a decrease in their annual yield collection. It is estimated that annual collection potential of Dashmool from the area has been reduced from 1200 quintals to 350 quintals in the last 4-5 years. Trees of *Terminalia chebula, T. bellerica, Aegle marmelos* and *Phylanthus emblica* are on steep decline in the forests due to the activity of Gujars, who cut down the trees and their branches for fuel and cattle feed. The grazing of animals has a similar effect in herb population. The piston effect of urban, industrial and farmland sprawl has greatly thinned the population of *Tribulus terrestris, Calotropis* species, *Acacia nilotica, Tephrosia purpurea, Centella asiatica, Uaria picta* and *Ipomea turpethum* in Haridwar - Rishikesh area.

TABLE 28.2

Important Medicinal Plants of the Ganga - Shiwaliks

1.	*Abrus precatorius*		50.	*Catharanthus roseus*	
2.	*Abutilon indicum*		51.	*Cedrela toona*	
3.	*Asparagus racemosus*		52.	*Celastris peniculata*	D
4.	*Acacia catechu*		53.	*Centella asiatica*	
5.	*Lawsonia inermis*	C	54.	*Chenopoduim ambrosoides*	
6.	*Grewia oppositifolia*	C	55.	*Cissampelosa pararia*	D
7.	*Acacia* sp.		56.	*Cinnamomum camphora*	
8.	*Acacia nilotica*	R(I)	57.	*Citrullus colocynthus*	
9.	*Adiantum* sp.		58.	*Cochlospermum gossipium*	
10.	*Acalypha indica*		59.	*Costus* sp.	
11.	*Acorus calamus*		60.	*Crataeva nervula*	
12.	*Achyranthus aspera*		61.	*Curcuma longa*	
13.	*Adhatoda vasica*		62.	*Curcuma aromatica*	
14.	*Adina cordifolia*		63.	*Cymbopogon* sp.	
15.	*Aegle marmelos*	D	64.	*Cynoglossum* sp.	
16.	*Albizzia lebbeck*		65.	*Cynodon dactylon*	
17.	*Albizzia odoratissima*		66.	*Datura fastuosa*	
18.	*Albizzia procera*		67.	*Datura stramonium*	
19.	*Amoora rohituka*		68.	*Desmodium gangeticum*	
20.	*Anogeissus latifolia*		69.	*Dioscorea bulbiflora*	D
21.	*Argemone mexicana*		70.	*Dioscorea* sp.	
22.	*Arundo donax*		71.	*Dolichos biflorus*	D
23.	*Artemisia* sp.		72.	*Eclipta alba*	D
24.	*Asclepias curassavica*		73.	*Emblica officinalis*	D
25.	*Asparagus* sp.	D (I)	74.	*Eugenia jambolana*	
26.	*Averrhoa carambola*		75.	*Euphorbia thymifolia*	
27.	*Azadirachta indica*		76.	*Euphorbia nerrifolia*	
28.	*Baliospermum montanum*		77.	*Euphorbia hirta*	
29.	*Bacopia monnierei*		78.	*Evolvulus alisnoides*	
30.	*Barleria* sp.		79.	*Ficus religiosa*	
31.	*Barleria prionitis*		80.	*Flacourtia* sp.	
32.	*Barringtonia actuangula*		81.	*Gardenia gummifera*	
33.	*Bassia latifolia*		82.	*Gloriosa superba*	
34.	*Bauhinia variegata*		83.	*Gmelina arborea*	
35.	*Boerhaavia diffusa*		84.	*Convolvulus pluricaulis*	
36.	*Boerhaavia rependa*		85.	*Hedychium spicatum*	
37.	*Briedelia verrucosa*		86.	*Heliotropium escliwaldii.*	
38	*Bryonopsis laciniota*		87.	*Heliotropium indicum*	
39.	*Buchnania latifolia*	G	88.	*Hemidesmus indicus*	
40.	*Butea frondosa*		89.	*Hibiscus abelmoschus*	
41.	*Caesalpinia bonducella*		90.	*Hibiscus rosasinensis*	
42.	*Calotropis gigantia*	LF	91.	*Hiptis suaveolens*	
43.	*Calotropis procera*	R	92.	*Holarrhena antidysentarica*	
44.	*Calendula officinalis*		93.	*Ichnocarpus frutescens*	
45.	*Cannabis sativa*		94.	*Ipomea turpethum*	R
46.	*Casearia tomentosa*		95.	*Leea aspera*	LE
47.	*Cassia fistula*		96.	*Lawsonia inermis*	
48.	*Cassia tora*		97.	*Leptadenia reticulata*	D
49.	*Cassia sophera*		98.	*Madhuca indica*	
			99.	*Malvastrum coromandalinum*	

(Contd.)

TABLE 28.2 - *Contd.*

100.	*Mangifera indica*		133.	*Smilax aspera*	
101.	*Melilotus philipinensis*		134.	*Sida* sp.	
102.	*Momordica balsamina*		135.	*Solanum indicum*	D
103.	*Medicago sativa*		136.	*Solanum* sp.	
104.	*Mentha pipereita*		137.	*Solanum nigrum*	
105.	*Moringa oleifera*		138.	*Solanum torvum*	
106.	*Nerium odorum*		139.	*Solanum verbascifolium*	
107.	*Nyctanthes arbortristis*		140.	*Solanum xanthocarpum*	
108.	*Oxalis corniculata*		141.	*Spondias pinnata*	
109.	*Ocimum* sp.		142.	*Stellaria media*	
110.	*Pedalium faetida*		143.	*Stereospermum suaveolens*	
111.	*Phyllanthus nirun*		144.	*Syzygium cummuni*	
112.	*Piper longum*	D	145.	*Tabernamontana coronaria*	
113.	*Plumbago zeylanica*		146.	*Tecomella undulata*	
114.	*Plumeria acutifolia*		147.	*Terminalia arjuna*	
115.	*Penstrophe bicalyculata*		148.	*Terminalia ballerica*	D
116.	*Polygonum uniparum*		149.	*Terminalia chebula*	D
117.	*Pongamia glabra*		150.	*Terminalia tomentosa*	
118.	*Psoralia corylifolia*	D	151.	*Thevetia nerifolia*	
119.	*Pueraria tuberosa*		152.	*Thuja occidentelis*	
120.	*Punica granatum*		153.	*Tinospora cordifolia*	
121.	*Quercus* sp.		154.	*Tribulus terresteris*	D
122.	*Ranunculus sceleratus*		155.	*Tridax procumbens*	
123.	*Rauwolfia serpentina*	R	156.	*Trienthema* sp.	
124.	*Ricinus communis*		157.	*Trigonella foenumgraecum*	
125.	*Ruellia tuberosa*		158.	*Tylophora indica*	
126.	*Rungia parviflora*	R	159.	*Urgenia indica*	
127.	*Saraca indica*		160.	*Uraria picta*	LE
128.	*Salmelia malabarica*		161.	*Vernonia anthelmintica*	
129.	*Sida cordata*		162.	*Vitex negundo*	
130.	*Sida cordifolia*	D	163.	*Withania somenifera*	D
131.	*Sida obovata*		164.	*Zingiber officinale*	
132.	*Sida rhombifolia*		165.	*Zizyphus maurtiana*	

R (I) = Rare (Imported)
D (I) = Dwindling (Imported)
D = Dwindling
LE = Locally Extinct
R = Rare
C = Cosmetic

There is an urgent need to conserve this wealth. Some medicinal plants may have to be taken on priority basis for growing on hills, river banks, roadsides. Whenever advisable mixed population of plants yielding drugs, timber, pesticides, detergents, oils, energy and those effective in checking soil erosion and in increasing soil fertility has to be grown in suitable places i.e., hills, river banks, road-sides, farms and degraded lands. This requires a well planned strategy in which the local population should actively participate. Model plantation could be set, their benefits, methodology and economics to be understood by people for acceptance and extension of the programme. Industrialists, Ashrams, Institutions and voluntary agencies may be persuaded to adopt certain areas for the purpose. The role of Government agencies is obvious. Their cooperation is essential. Required literature spelling out the details of the whole excercise to be performed, its economics, protection of plantations, their maintenance etc. should be available to those who take the job.

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29

Socio-economic Study of the Stretch from Bally to Bandel

K. G. BAGCHI & T. M. DAS*

The study area (22° 39' N to 22° 56' N, 88° 15' 30'' E to 88° 33' E) covers the stretch of the Hugli from Bally to Bandel and the total area is 600 sq km. (Figure 29.1). The Saraswati river, a distributary of the Hugli to the west demarcates the western limit and Sunti yet another distributary, marks the eastern limit of the study area. It is observed that the average run-off of this stretch of Bhagirathi is about 150 thousand cusecs during the rainy season (June to September) but it has a lean flow during the rest of eight months. Again, up and down movements of water, due to tides, cause temporary suspension of the water current during the change-over period between tidal ebb and flow resulting in heavy sedimentation. The newly developed emerging shoals of Bally, Khardah, Bandel and large pointbar depositions near Baidyabati and Chunchura pose hazards for the navigation.

Waterlogged areas behind the levees are mostly found along the left bank of the river. Waterlogging indicates high water tables, susceptibility to water pollution by contamination of surface and percolation water having both toxic chemicals and bacteria.

Consequent to the mounting population pressure, the arable lands are being intensively cultivated. This high farming intensity indicates application of increasing quantum of fertilizers to the land. The growth rate of consumption of fertilizers (1970-71 to 1980-81) in Hugli district is about 91 per cent and in 24-Parganas is about 163 per cent. Most of the agricultural plots drain into the Hugli river directly and through the canals indirectly.

In consequence there is every likelihood of unabsorbed chemical components of fertilizers finding their way with runoff into the Ganga.

In addition to the Jute and Textile industries large numbers of small and large chemicals, rubber, plastic factories have grown up during the last three/four decades. Due to functional deterioration of the river, most of the factories have aligned themselves on roadways and railways, thereby impounding drainage disposal and introducing complications by way of spreading out pollutants over their hinterlands. Emission of smoke from the chimneys of the newly developed industries, constant sound of the machines, disposal of toxic materials to the local unmetalled drains etc. pose health hazards to the people. The occurrences of asthma, respiratory tuberculosis, hearing problem are high among the children (upto the age of 15). Cases of dysentery, diarrhoea and skin diseases are gradually increasing for the last few years.

The environmental sanitation conditions of the 18 urban centres covered in this study were so miserable that it is hardly worthwhile to term them as urban Centres. Sanitary latrines are provided for less than 40 per cent of the population. Therefore, the use of open space as toilet is a common practice here which creates pollution hazards directly for the local water bodies in the interfluve and the Ganga itself. Most of the drains are unmetalled in which water stagnates and these are the breeding grounds for mosquitoes.

The deterioration of the river regime has brought great tragedy to the local fishermen and to the boatmen. The quality as well as the quantity of the fish are gradually reducing year after year, after contact with the toxic Ganga water, so that the fishing business, which was once a thriving one, has almost been crippled at Uttarpara, Dakshineswar, Chandannagar etc. All weather transportation of the raw materials and the finished products by way of excellent water ways, which the river once was, is now limited only to the rainy season and that too for restricted stretches. Former trading routes are now remembered nostalgically rather than being made use of.

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Physiography

The fairly flat land surface with southward slope is the general land-form characteristic of the basin. This region is geologically demarcated as the mature part of the lower Bengal Basin. From the Bench Mark (B.M.) study of the river Hugli it is found that near Naihati and Chunchura (northern part) the B.M. are 8.2. mts., 8.8 mts., further down at Bhadreswar the values are 5.4 mts., 5.7 mts., but below it the values become slightly higher like 7.3 mts., 8.2 mts., and downwards from Ichamati the value again decreases to 5 mts.

Saraswati river, western boundary of the region, was once the main stream of the lower Bengal. Saptagram (place of first settlement) was formed during that period on the bank of the Saraswati. Trade ships used to ply freely along the course of the Saraswati river. It seems that by the end of 16th Century, the course deteriorated to a great extent and during 17th and 18th Centuries the shifting of the course demolished many historic places, situated on the banks. Now, only during rains it looks like a stream. The Saraswati – Hugli interfluve region is much narrower in the northern part and gradually becomes wider. Settlements are developed along both sides of the G.T. Road on the levees. Further west below the embankment there is gently sloping low lands. Scattered small marshy land and agricultural fields are dominant here, settlements are developed surrounding these agricultural fields.

The eastern boundary is Sunti river which drains over the great plain in a tortuous course. The interfluve area in between the Sunti river and river Hugli east of the embankment is studded with large marshes namely Bariti Bill, Malati Bill, Khagra Bill etc. The average altitude of this part is about 6 metres. Some portions of these marshes have been reclaimed nowadays for the growth of settlements.

Flow Character and Sedimentation

It is ascertained that due to local heavy rain as well as the inflow of the water from the upper stretches of the river, the flow is maximum in this Bhagirathi – Hugli stretch during the four monsoon months. It causes floods almost every year. During high freshets, over 150 thousand cusecs of water runs down the river near Calcutta, while in the leanest period it goes down to a mere trickle of only 12,000 cusecs. The flow of this lower stretch is also gradually decreasing. It was estimated that in 1919 (August to September) the discharge was 1,10,000 cusecs but in 1971 it was only 40,000 cusecs. Moreover the rate of sedimentation is increasing. At present, on an average, 0.42 gm sediment remains per litre of water and during rainy season it becomes 1.70 gm per litre (Port Commission of Calcutta).

The flow is highly variable in accordance with the tidal effect. The up and down movement of the water periodically causes temporary suspension of the water current during the period between the tidal ebb and flow. As a result the process of the removal of the pollutants is slow and difficult. It is estimated that 560 cubic metre sediment is deposited per hectare area in each year.

Soils

There is not much variety in the soils of the plains. All of them are alluviums transported by the Ganga and it can be designated as Gangetic alluvium. New alluvium covers mainly the river bank side. In certain areas, silt deposited from the Hugli and along the old course of the Saraswati river, clayey soil has developed.

Climate

The study area has tropical, hot, humid and monsoon type of climate. Average temperature of the area is 26.27° C and the range of temperature varies with the season. During summer the range is 38.85° C maximum, 19.77°C minimum and with the advent of the rain the range of temperature decreases, during wet season it is 35.59°C maximum, 23.36° C minimum.

The maximum rain occurs after the bursting of the monsoon and continues upto the month of September. During wet season the average rainfall is about 300 mm. The north-western part receives about 1475 mm yearly rainfall whereas the area below Barasat has about 1575 mm rainfall yearly.

Late arrival and early departure of monsoon creates a great problem. On the basis of the variability of wet season rainfall of 45 years (1931 – 75) it is found that the values are generally on the positive side, – 190 & + 402 in this low Gangetic region.

Before the onset of the monsoon and at the vacating stage of the monsoon, deep depressions of cyclonic nature develop and bring disasters to the area.

Land Use

The present land use pattern of the area was studied. The data for 1944-45 have been taken from Ishaque's report and the data of the last thirty years have been obtained from the office of Directorate of Agriculture, Government of West Bengal (Figure 29.1).

On the basis of the land use pattern 3 broad zones could be demarcated:

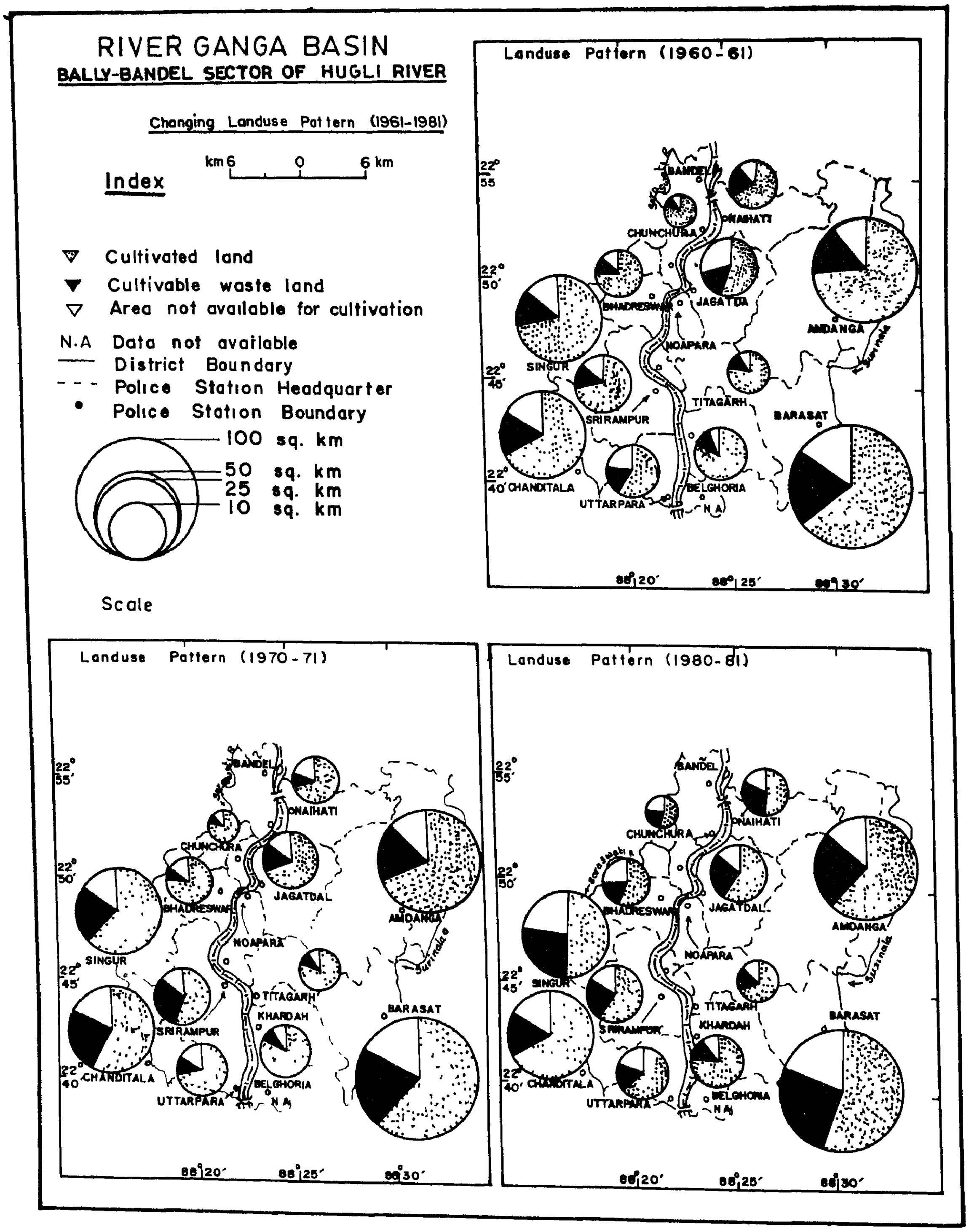


Figure 29.1 : Changing Land Use Pattern of the Study Area (Data were taken in 1960 - 61, 1970 - 71 and 1980 - 81)

(1) Central part along both banks of the river Hugli predominated by industry which includes Naihati, Jagatdal, Noapara, Barrackpore, Titagarh, Khardah, Belghoria, Uttarpara, Srirampur, Bhadreswar, Chandannagar and Chunchura police stations.

(2) & (3) Two elongated belts away from the Central one along both banks of the river where cultivated fields provide the main land use pattern. It includes Habra, Amdanga and Barasat police stations along the eastern bank and Chanditala and Singur police stations along the western bank.

The area available for cultivation has been shrinking steadily, particularly for the last 30 years, due to the continuous increase of urbanization and industrialization specially in the central zone of the area.

Percentage of Land Use to Total Area of the Police Stations

The forest lands stand completely obliterated. Though the cultivated lands increased during the first twenty years (1944 – 45 to 1960 – 61) there is now a tendency for decrease during 1960 - 61 to 1980 - 81 in almost all the police stations. On the contrary, the area not available for cultivation is gradually increasing and percentage of cultivable waste lands is also increasing.

Though the area is mainly constituted of the productive river-borne alluvium yet industries provide more employment compared to agriculture. Therefore, the immigrants have mainly engaged themselves as industrial labourers rather than as agricultural labourers.

Though the percentage of the cultivated land is decreasing, still there is an abnormal increase in multiple cropping of land. Crop production is also not increasing much with increase of fertilizer consumption (Table 29.1 and 29.2).

From the analysis of the aerial variation of the distribution of land use parameters it is found that within 2 kms away from the banks along both sides of the river there are very high concentration of residential and industrial establishments. But densities of both are gradually decreasing away from the river banks and on the contrary agricultural holdings are increasing. The notable land use pattern is the development of many orchards along the side of the river. Below the embankments marshy lands are still found in patches.

TABLE 29.2

Crop Production tonnes/km^2 for Two Districts

Year	Hugli	24 - Parganas
1970–71	474.28	150.52
1980–81	531.51	156.14
Growth rate (per cent)	12.06	3.73

Industry

History of industry of this region is the history of 200 years. Though nowadays many age-old (Jute, Cotton etc.) industries are facing various problems still, the belt is marked as one of the important industrial concentrations of West Bengal. The number and type of registered factories of the Police Stations were obtained from the office of Registrar of Small & Large Scale Factories, West Bengal. A comparison has been done between two decades 1961 and 1981. The number of all types of industries have increased, but remarkable are the textile industries, chemical industries, paper manufacturing industries, steel and brass metal industries and automobile industries (Table 29.3). The number of miscellaneous industries in the region also cannot be ignored.

It is indeed true that the increase in the number of industries indicates a picture of growth, but in this some problems are associated. By investigation it is found that most of the industries are situated just along the bank of the river Hugli and they directly or indirectly dispose off their waste materials, burnt oil, acid etc. to the river without any pre-treatment of effluents. The

TABLE 29.1

Nature of Fertilizer Consumption of Two Districts

Year	Hugli Consumption of Fertilizers / km^2 (tonnes)			24-Parganas Consumption of Fertilizers / km^2 (tonnes)		
	N	P	K	N	P	K
1970-71	2.410	0.587	0.1777	0.395	0.057	0.006
1980-81	4.435	0.818	0.8250	0.833	0.168	0.207
Growth Rate	84.020	39.350	366.1000	110.890	194.740	3350
Growth rate of total fertilizer consumption (per cent)	91.49			163.75		

TABLE 29.3

Decadal changing Pattern of the Industries

Type of Industries	Total Number of Industries in the area	
	1961	1981
1. Agrobased	20	22
2. Wine and Cigarette	3	3
3. *Textiles*	74	113
4. Rubber & plastic products	10	24
5. Chemical	19	38
6. Ceramic	10	18
7. Paper products	4	15
8. Cement & building materials	10	13
9. Metal products	55	78
10. Machinery	38	36
11. Automobile	3	10
12. Miscellaneous	23	42

scholars of other disciplines (Agricultural and Life Science Dept.) associated with this investigation have analysed the water of selected spots and from their analysis it is found that the waste materials of the textiles are bleaching powder, colour and dyechemicals, and of paper mills are sulphate acid radical (SO_4^{2-}), paper and board chips. From the chemical factories derived are acid, raw chemicals like sulphuric acid etc. From the field enquiries it is also found that sometimes industrial oil and molasses are disposed in the river from WIMCO factory (Kamarhati), Shaw Wallace and other wine factories of Uttarpara.

An interesting point that arises is that with the increase in the number of industries the working population is not increasing proportionately, the ratio of the working population to the total population has decreased in 1981 as compared to 1961. This picture is more true of the 24-Parganas than that of Hugli district.

Demography

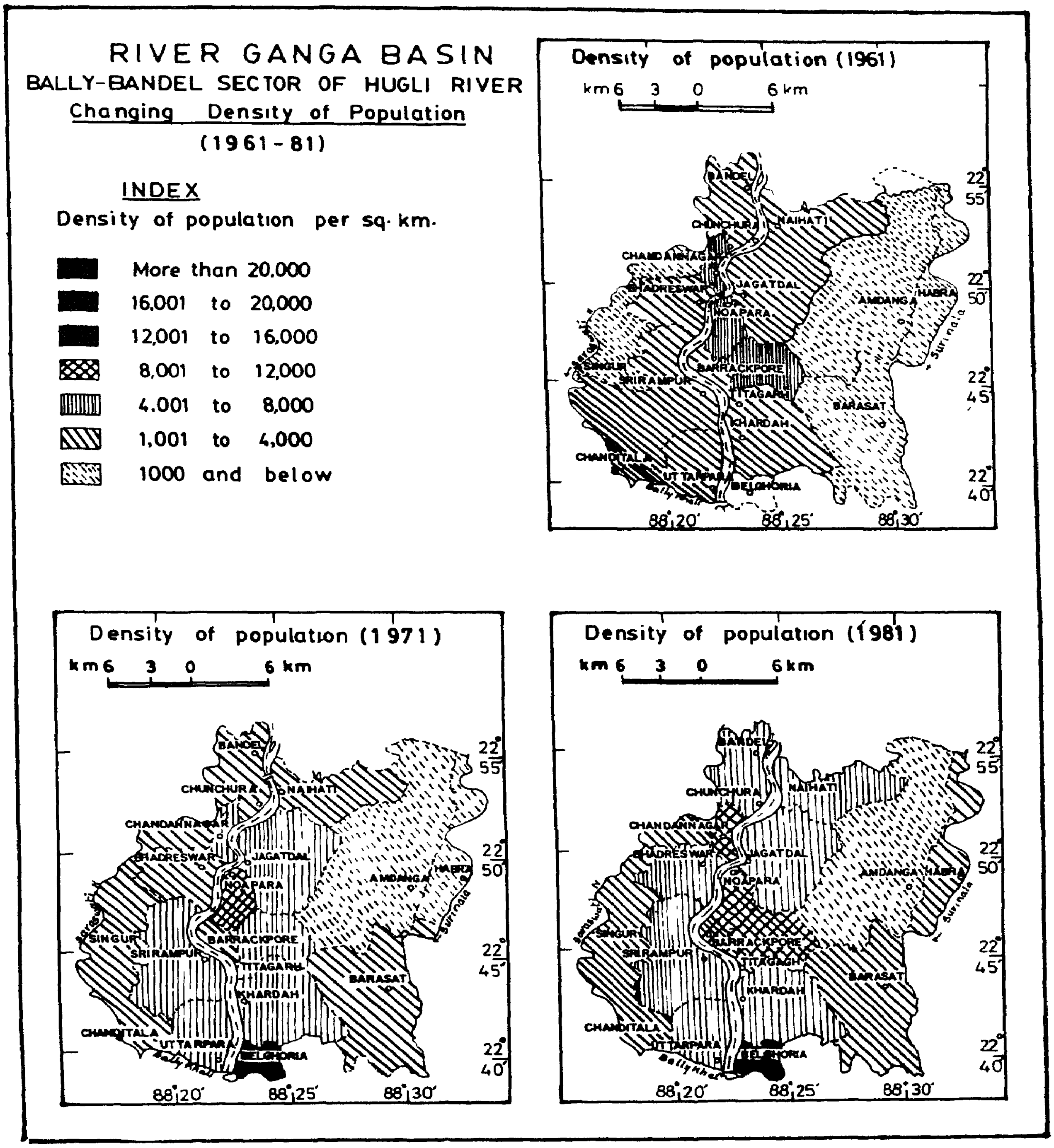
From the decadal analysis of the density of population it is noted that in 1961 the density along the bank varied from 3000 – 4000 per sq km but in 1981 density increased to 20,000 per sq km The growth rate of population has increased markedly after 1951 which may be due to the great inflation of population after Bengal partition. This high influx growth of population indicates heavy human load which the region bears at present and for the future (Figure 29.2).

It is interesting to note that though the population has increased considerably after 1950, the percentage of working population has gone down, i.e. in 1964 in agriculture dominated police stations, the average percentage of the working population was 26 whereas in 1981 it was 24 per cent. In the industrial belt of the area, the percentage is slightly higher. The average percentage of working population based on the total was 36 in 1961 but in 1981 it dropped down to 30. There has been a huge on-rush of population but in step with it, the occupational opportunities have not developed. Therefore, this heavy pressure of dependent population stood in the way of developing a prosperous economy.

TABLE 29.4

Nature of Water Supply of the Municipalities

Municipal Bodies	Population (1981) '000	Required Water Supply '000 (Litres/day)	Actual Water Supply '000 (Litres/day)	% of actual Water supply to the requirement
Chunchura	126	19,530	18,900	96.77
Chandannagar Municipal Corp.	102	15,300	8,075	52.77
Bhadreswar	59	7,375	5,005	67.86
Champdany	76	9,500	3,670	38.63
Baidyabati	70	8,750	2,798	31.97
Serampore	127	19,050	11,812	62.00
Rishra	81	10,125	8,000	79.01
Konnagar	51	6,375	2,170	34.04
Uttarpara-Kotrung	79	9,875	5,818	58.92
Naihati	114	17,100	5,940	34.74
Bhatpara	263	39,450	2,094	5.31
Garulia	57	7,125	1,730	24.28
North Barrackpur	81	10,125	1,639	16.19
Barrackpur	112	16,800	3,302	19.65
Titagarh	104	15,600	6,930	44.42
Khardah	45	5,625	4,410	78.40
Panihati	206	30,900	1,250	4.05
Kamarhati	240	36,000	7,825	21.74



re 29.2 : Decadal Growth of Density of Population of the Urban and Rural Police Stations Indicating the rapid Increase of Domestic Load in this Small Stretch

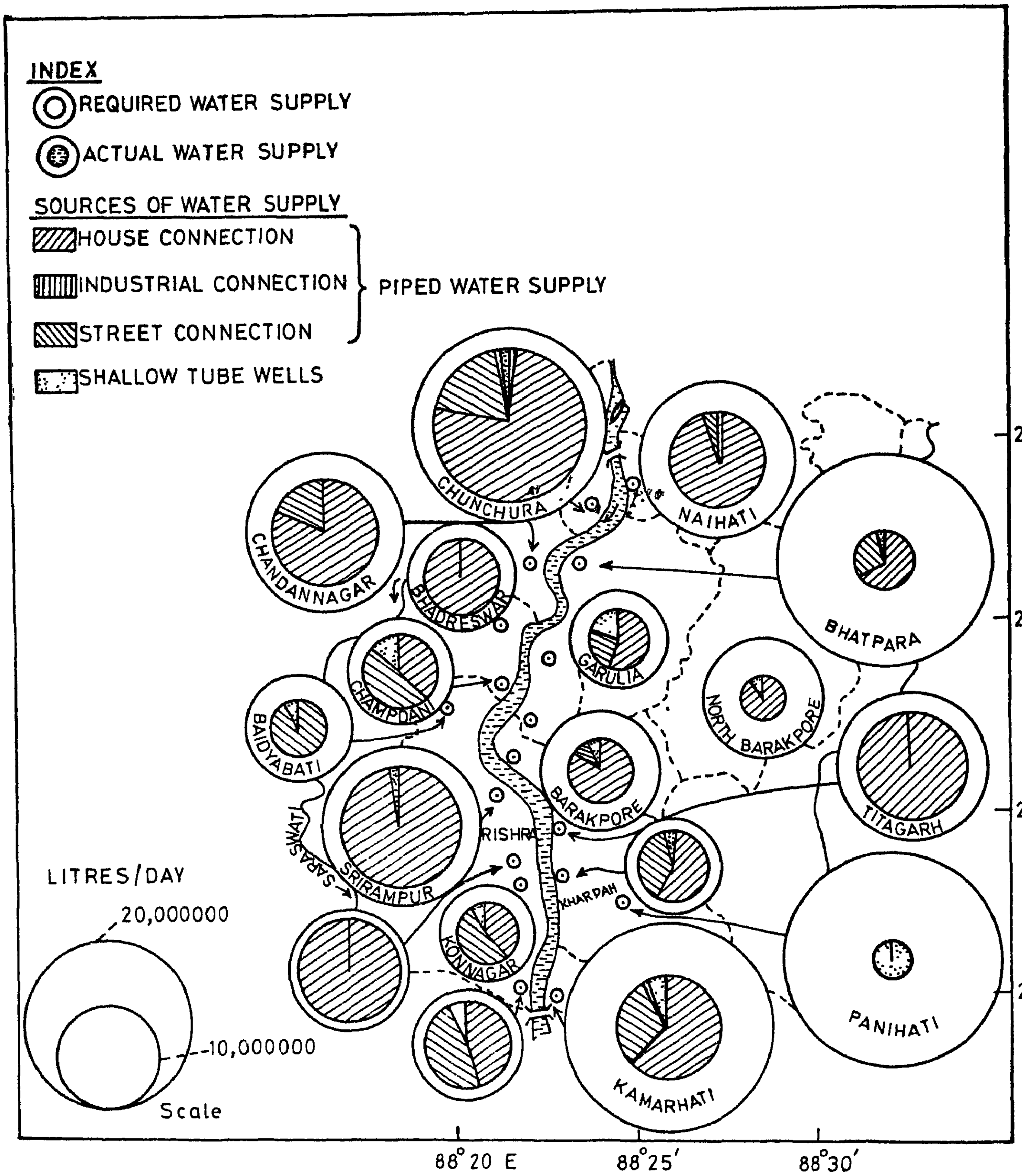


Figure 29.3 : Nature of Water Supply in the Ganga Basin (1980-81)

Water Supply

The area has 18 urban centres. Among these nine are Class I towns (population more than 1,00,000), but none of them enjoys adequate urban facilities. Organized water supply serves only a portion of population of these Class I & Class II towns. On the basis of the usual calculation of 150 litres per day per capita for the Class I towns and 125 litres for other towns, the required water for each of the municipal centres can be worked out. The comparison between the required and the actual supply denotes the insufficiency in the supply of water (Table 29.4, Figure 29.3).

Drainage and Sewerage System

Conditions of the drainage and sewerage are also miserable. More than 60 per cent holdings have service privy only. Three urban centres have restricted underground sewerage (5 per cent).

Most of the drains are *kucha* and open, in which water stagnates and forms breeding ground of mosquitoes and other pollution generating bacteria. In most of the towns *khatals* (dairy feedlots) are located along the side of the river from where huge quantities of raw cowdung are washed directly in the water. Moreover, domestic kitchen waste and other wastewater, including septic tank effluents are allowed into the street side drains and cleaning of those drains is sadly neglected. As a result during rainy season these drains as well as sewers often overflow and the water enters into the ground floor of many houses. Piling up of the waste material in the low land areas and along the side of the tanks are common phenomenon here. During rainy season polluted water from the decomposed waste material, enters into the water of the *kucha* wells by seepage and directly into the water of the tank.

Transport

During the 18th century the most important transport linkage was the river Hugli Rennal writes, "The Ganga and Burramooter (Brahmaputra) Rivers together with their numerous branches and adjuncts intersect the country of Bengal in such a variety of directions, as to form the most complete and easy inland navigation that can be conceived" There were three chief water routes, one from Calcutta via Chunchura, Hugli, Kamarhati, Kanchrapara, Nadia upto Bhagawangola of Murshidabad; second one from Calcutta to Patna direct, and the third one from Calcutta to Dacca, via Jalangi river (Murshidabad). From the report it is also found that many commodities like cotton and silk, sugar, indigo, opium etc. were exported from Calcutta Port during the 18th Century. All these materials were gathered at Calcutta port from Patna, Kashimbazar, Malda, Balasore, Radhanagore, Vishnupur, Faridpur, Murshidabad, Allahabad, Aligarh, Mirzapur, Jaunpur, Agra, Meerut, Lucknow, Azamgarh etc. It was a highly busy trading route.

But now the picture is completely different. The river transport has been abandoned. Small boats ply with commodities but their destination as well as the period of boating are limited. Now Ferry services are the only activity related to the waterways.

Navigational Problems

The gradual decrease of the annual flow of the river and the development of large number of shoals in different parts are the main causes of the disruption of the age-old navigational route. On the basis of the interviews with the boatmen of Serampore, Uttarpara and Dakshineswar ghat, it is known that about 10 years back this Hugli river was an important navigational route. During those periods, various types of commodities like pulses, oil, sugar, jute, cotton clothes, bamboo etc. were brought from Balagarh, Pandua, Farakka etc., and the boats plied upto Metiaburuz, Balurghat downwards to the wholesale markets. Large number of people were involved in those activities because they used to be engaged throughout the year with an uninterrupted navigation. There are about 6 to 7 families at Uttarpara ghat who came to this area from Jaunpur village of U P 40 years back and have witnessed this phenomenon.

The survey revealed that due to the reduced flow of water the boats cannot negotiate this long stretch nowadays. Although the transportation cost by lorry/truck is much higher, still the roadways are the only alternative left. Now the commodities are also limited to tiles, bamboos, bricks etc. From the interviews with the boatmen and the businessmen of the Serampore, Panihati, Ariadaha area, it is ascertained that nowadays only during the rainy season bamboos from Murshidabad, bricks from Uttarpara and grocery from Calcutta have come up to these ghats for local uses. During the lean period of the river, the dependency on the business is gradually decreasing During the dry period boats cannot be used between the stations. During dry period and ebb tide, the newly developed shoals emerge over the water surface, interfering with local navigation.

Fishing

Fishing was an important occupation of this area. A large number of families of riverine land had this occupation as a traditional one. About 15 - 16 years back large number of salt water loving fishes like Tapse, Bhola, Pharsa etc. were found in the Hugli river abundantly. But now these species have almost disappeared. Hilsa was once the pride of Bengal and was found throughout the year in this part. But now these are found only from the months of July to September. The size as well as the quantity of the fish have decreased. On an average the catch is only 15 - 30 kg fish per boat per month. Once lobster was also found in large quantity but now there is no trace of it. Local fishermen reported that they have observed lobsters to die within a few days when the urban effluents were cast into the Ganga from the surrounding municipal centres to the river water directly.

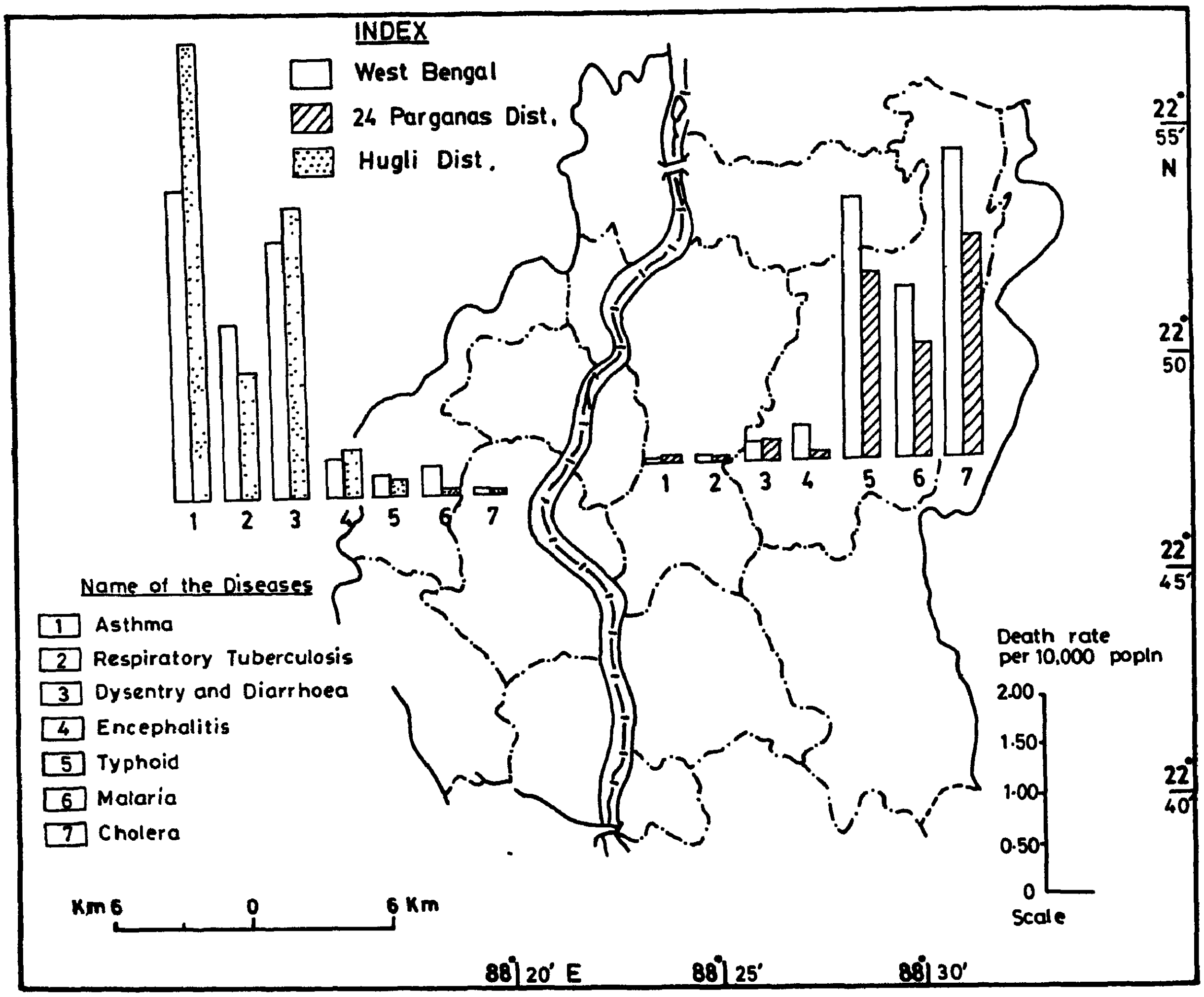


Figure 29.4 : Death due to Different Diseases (1980)

Sometimes during rainy season alkalies are poured into the Hugli river from the chemical factories of Rishra. In 1985 during winter burnt oil was spread out into the river water from Titagarh Thermal Power Plant. Engine lubricant oils are also discharged from oher factories and steamers. This oil enters the fishing net and makes it unusable. Fishes also could not sustain themselves in this oil covered water.

Health Hazards

In addition to the changing occupational patterns the effects of pollutions are widely visible in the health of the local people. In this regard some statistical information from the Public Health Department have been collected which reveal a very dismal picture (Figure 29.4).

In relation to state average the incidence of asthma and respiratory tuberculosis is very high in the Hugli and 24-Parganas districts.

The local physicians report that the outbreak of dysentery and diarrhoea is an annual feature during the rainy season. Defects in hearing are mostly found among the children (upto the age of 15). According to the local physicians emission of smoke from the low height chimneys of the newly developed industries, blown out dusty waste materials of the factories such as the thermal plants, rubber factories, galvanising factories etc. and also the constant noise of the machines affect the health conditions of the people. Disposal of toxic materials to the local unmetalled drains, and use of water from the open tanks are not uncommon practices.

In response to the needs of the high density of working immigrant population *bastees* have developed in many places sharing the common wall with the factory. In the congested Belghoria and Kamarhati localities, the toxic smoke from factories cause breathing trouble, giddiness and irritation in the eyes

A stream of burning ghats using wood as fuel are situated along both sides of the river. Floating of the unburnt portions of corpses and carcasses is a common scene. Above all sometimes oily discharges contaminate the water of Uttarpara, Titagarh and form a black scum over the water. The people hesitate to take their baths in this water during such condition. As a result, the potability of the water is affected and bathing in this water causes skin diseases and allergy.

The dependency on the river is gradually diminishing. Due to the high density of population man - land ratio is very high. The extension of the agricultural land and the industries are restricted. As a result a huge load of unemployed working force continue to be deprived of gainful employment. A tendency for antisocial activities is inevitable under such circumstances and result in frequent manifestations along both sides of the river. This might be considered as a social pollution. If we consider the present sewerage condition of the municipalities as well as the health hazards of the people and the opportunities of education and employment it is hardly permissible to term this region as an important developed urban stretch of the CMDA.

Measures for the Amelioration of the Problems

1. Schemes should be taken up for draining out the marshes as these are the potential sources of water pollution during rainy season.
2. The municipal authorities should be made to build an adequate sewer system and improve the existing services.
3. A zonal treatment plant may be installed to treat the waste effluents from the industries and municipalities before discharging into the Ganga. This may be done on a zonal basis consistent with viability.
4. Alongwith the improvement of the sewer system proper arrangements should be made for augmenting the filtered water supply of municipalities and factories.
5. All service privies should be replaced by sanitary latrines.
6. Enhancement of the lean season flow is one of the most important aspects to reduce the rate of sedimentation. This will prevent the gradual rise of the bed and consequent reduction of volume of the stream.
7. Arrangements for water analysis should be made available to each municipality which will guide water quality for public use.
8. Farmers should be encouraged to extend the orchards. This will diversify land use and provide additional income.
9. Awareness should be created of the hazards of the use of open pond water, shallow tubewell water. Side by side proper arrangement for pure water supply should also be made.
10. The riverine lands are congested with a large number of factories and high density of population. New establishments, large, medium and small should be built up in the low density area for creating necessary developmental balance.

30

Socio-Economic Study of the Ganga from Rishikesh to Garhmukteshwar[*]

T. M. DAS

A socio-economic study was undertaken at the upper stretch of the Ganga from Rishikesh to Garhmukteshwar. The data were collected from 712 villages in specially designed forms distributed to villagers. People earn their livelihood mainly by farming or by working as labourers. Only few persons are in service or doing some small business. The list of blocks covered under study is given below:–

District	Block
Saharanpur	Bahadrabad
Bijnor	Jalipur
	Mohammadpur Deowal
	Haldaur
	Najibabad
Moradabad	Gajraula
	Dhanaura
Ghaziabad	Garhmukteshwar
Meerut	Hastinapur
	Parikshit Garh
Muzaffarnagar	Morena
	Jansath

A number of villages suffer from erosion, seepage, water-logging and floods Khadar lands and village lands are not properly managed. There are suggestions from the villagers that trees should be planted on a large scale on such lands and after-care should be provided. The low yield of milk from cow or buffaloes was due obviously to the neglect of these animals and to poor and insufficient diet. There are suggestions that "Milk production committees" be constituted in the villages to improve the situation.

It was significant that ponds did not exist in many villages. However, in cases where they were present, fish production was practised. There are suggestions that ponds should be dug in the village for receiving domestic wastes for irrigations and fish production.

In general medical facilities are poor or do not exist even in the villages having a total population of 2,000. The picture on education front is dismal. There are no schools in a number of villages. Where they exist the teacher to student ratio is poor, 1:45 to 1:57. Buildings are in a dilapidated condition. In the villages located near Gajroula Industrial Complex it is reported that crops and animals are adversely affected by the industrial effluents. People living in Lakkarghat area and near Bijnor barrage had to change their profession due to the ecological degradation caused respectively by Indian Drugs and Pharmaceuticals Ltd. (IDPL) effluents and water storage.

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[*] Based on work carried out by Prof V Shankar at Gurukul Kangri Viswavidyalaya, Haridwar

31

Environmental Awareness of the Problems Related to the Ganga*

T. M. DAS

Under the present programme five Universities were offered grants to conduct environmental awareness programme. They held Environmental Awareness Workshops at different venues and dates.

Active participation of the public is obligatory for the abatement of deterioration of environmental qualities of varied nature. In majority of the cases environmental problems are generated locally through the cumulative action of many little misdeeds constantly committed by the common people, consequences of which are hardly clear to them. Greed and illiteracy are the two formidable barriers that stand against any change of these unwholesome practices. However, the people are mentally alert and responsive. If important information is disseminated in proper form couched in intelligible language, there is every possibility that they would respond to them with faith and motivation.

The programme of environmental management has three components. The first is to bring all the people of the country, literates-illiterates all alike, under a well planned environmental awareness forum. A meaningful understanding and co-operation from the public is an obligatory factor for maintaining the minimum standard and stability of environmental qualities. The second step is to conduct interdisciplinary researches on various environmental problems and to find out the roots of these maladies with remedies. The third step is to implement these findings with the help of various Governmental and Non-governmental agencies. Hence, the role played by the common people and Non-Governmental Organisation (NGOs) is irreplaceable in maintaining environmental qualities.

In order to get tangible results in this field a wide net-work of awareness programme covering the entire course of the Ganga is found necessary. In this net-work of awareness programmes, Non-government Orgnisations, science clubs and various institutions should play their appropriate roles. Local leaderships should be built up. They should study the nature and depth of local problems and motivate the common people by furnishing them with proper information in a participatory manner.

There is a need for setting up three Centres for the network of environmental awareness programme one each at the lower, middle and upper stretches of the Ganga. These Centres should be provided with necessary equipments: staff, books, journals, films, slide projectors, overhead projectors, 16 mm and 8 mm movie projectors, cameras, video systems, photo-copy machine, etc. for running the network programme in collaboration with non-governmental agencies. These Centres, in turn, should maintain an inventory of local resources, e.g. names and addresses of local NGOs, Government Institutions, Libraries, books and journals. It is heartening to note that there are more than 300 NGOs all over the country working in the field of environment, and more than 200 science clubs are located in West Bengal alone. These three Centres also should prepare their own materials for dissemination, e.g., booklets in local languages, charts, models, maps, colour slides, movie films, video tapes, banners, slogans etc., and also should arrange short training courses, workshops, seminars to elevate the capacity of the people who matter.

Environs Vol. I & II have been published as an outcome of the Calcutta Workshop. As a follow up of the Calcutta camp more than 140 lectures with demonstration of colour slides were arranged between 1984 to 1988. This follow up programme has proved to be very effective in generating interest about the environment and the Ganga among the common people.

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*The following five Principal Investigators conducted environmental awareness programme : Prof. Dilip Bose, Jadavpur University, Prof. T.M. Das, Calcutta University, Prof. S. Mukhopadhyaya, Bidhan Chandra Krishi Vishwavidyalaya, Prof. A.K.Sinha, Kanpur University and Prof T. P. Singh, Banaras Hindu University.

Each Centre in the Network of Environmental Awareness Programme should have two functional components:

1. Collection of information and their analysis, evaluation and documentation.

   Comprehensive studies on the socio-economic situation of the Ganga basin are urgently needed for the proper and healthy development of this vast area. Only a very small area has been studied so far. The picture that has emerged is depressing. Statistically sound field surveys should be conducted for the collection of primary data. The secondary data should be checked and updated. The collaboration of other authorities who are working in this or allied fields may be sought.

2. Dissemination of information in collaboration with various Governmental and Non-governmental agencies. It would include holding of popular lectures, workshops, symposia, short technical courses, inter-state exhibitions. It would also include writing and publication of booklets, banners, slogans, preparation of colour slides, documentary movie films, video tapes, models, charts, etc. The Centre should take special care to build up local leadership with the help of Non-governmental agencies and furnish them with action oriented information, who would in turn motivate the common people.

Each Centre should have an Advisory Committee taking representatives from various organizations working on the Ganga basin as well as from public institutions, science clubs and experts in environmental sciences. Such Environmental Awareness Programmes may be sponsored jointly by Governmental and Non-governmental Agencies.

32

The Scientific Study of the Ganga: Perspectives

C. R. KRISHNA MURTI

There is voluminous documented information on the hydrology of the Ganga based on which the river has been, in a sense, overexploited for irrigation. In contrast, our knowledge of the limnological characteristics of the river as a whole is fragmentary. Barring the surveys on the productivity of carp and other edible fish of the Ganga serious attempts have not so far been made to prepare taxonomically supported inventories of the flora and fauna of the river basin.

An Integrated Action Oriented Environmental Research Programme on the Ganga was enunciated in the early part of 1983. The related projects were initiated in the universities of the upper and lower stretches of the River in October–November 1983 and the middle stretch in late 1984. Work on the stretch from Narora to Kannauj and Kannauj to Shuklaganj (Kanpur) was started only in 1987. The first phase of the programme was designed primarily to study the hydrobiology of the river and its relevance to self-purification reportedly occurring in many points despite heavy pollution due to human activities.

The investigations pursued by the universities aim to fill some of the gaps in our knowledge of the hydrobiology and bioresources of the Ganga. Admittedly, without precise knowledge of these characteristics, no plan on cleaning the River can be expected to be complete

The activities envisaged –

(i) a core programme to be carried out by all the universities on the stretch allotted to them in order to collect data on 18 water quality parameters and make an inventory of phytoplankton, zooplankton, benthic species, and

(ii) specific projects dealing with medicinal plants, microphytes and macrophytes possibly playing a role in protecting the banks, geomorphology of inorganic sediments and their possible role in the cycling of heavy metals, modelling of water quality, development of indigenous instruments to monitor important water quality parameters, effect of pollutants on the physiology of the carp, the ecology of water-borne diseases, isolation of enteric viruses and enterophages and identification of bioindicators of chemical pollution.

About one thousand young research scholars and teachers in fourteen universities participated in the programme demonstrating their readiness to undertake multidisciplinary research and, what is more, their willingness to be subjected to coordination and quality control of the data generated by them. In the process they have acquired a reasonable degree of capability in undertaking mission-oriented investigations relevant to river management. The talent pool generated in the university systems can now be gainfully used in strengthening the scientific base of the Ganga Action Plan. In undertaking the action oriented research programme, the academic community faced a challenge quite different from that of commonly pursued university research. Sample collection, analysis and field observations all involved painstaking efforts of a different kind. And yet out of this work has now emerged leads for exciting basic research in the coming years.

Deployment of common methodology and instruments and quality assessment of performance for reproducibility of data have enabled the university scientists to generate:

(a) data for laying down pristine standards of water quality of the river, and

(b) data on the entire length of the river on physico-chemical parameters which will be the basis for a mathematical modelling exercise of the river water quality.

The hydrobiological study of the river, besides giving a picture of the current limnological status of the river, has led to –

(a) The inventorisation of the algal species for the first time. The significant finding was the prevalence of clean water diatoms in the pristine region and their gradual ecological succession into the green and blue green algae with potential for creating "blooms" when the river passes through the plains of U. P. and Bihar. It is well known that such blooms due to intense photosynthetic activity release oxygen. While, on the one hand, this may be useful for meeting the deficiency of dissolved oxygen and neutralising the near anaerobic conditions, on the other side, by preventing the penetration of light into benthic depths, the blooms adversely affect the food web for fish. With the taxonomical work on the voluminous data collected almost completed, an algal atlas of the Ganga, a dynamic semi-tropical riverine ecosystem, can be prepared. By their relative preponderance or disappearance against the changing pattern of water quality of the river, some of the algal species encountered in the Ganga have been shown to be pollution indicators.

(b) An almost complete inventory of the aromatic and medicinal plants of the upper region of the basin has been prepared. This should prove useful to agencies interested in their propagation for commercial use in the drug and perfume industry.

(c) Micro and macrophytes including grasses and reeds, trees and herbs indigenous to the basin have been identified and enumerated. Attempts are being made now to set up nurseries of selected species which are fast disappearing from the basin. Microphytes and macrophytes of the local habitat have to be re-established without any further loss of time at the bend of the river near Kalakankar in U.P. and other areas in Bihar which are subject to perennial erosion in the flooding season.

(d) Fungal species known to play a key role in the conversion of litter to available carbon in the energy cycle or fixed carbon in the form of humic acid have been identified throughout the stretch of the river. Complete enumeration by using modern tools of taxonomy would lead to a source of organisms of potential use in biotechnology. Some of the fungi appear to be typically aquatic or to have become fully adapted to a flowing aquatic system after migration from the nearby terrestrial region. They readily digest lignocelluloses, the main component of biological wastes and recycle the carbon.

(e) A large number of protozoa and other forms of zooplankton has been identified. There is indication of some close interaction of the zooplankton with aquatic insects. As expected there is wide variation in the variety and density of the organisms as one moves from the relatively pristine upper stretch to the highly used regions of the river in the plains.

Partial success has been achieved in completing the design and development of an instrumentation system for in-situ sensing and storage of some water quality parameters and their transmission by telemetry. Development of circuits for *p*H, dissolved oxygen, electrical conductivity and temperature has been completed with indigenously available components at the laboratory bench-scale level. A prototype has been set up for transmission and retrieval of monitored data at two stages – from the floating buoy containing the monitoring instruments to the shore based antenna and from the antenna to the State Laboratory at the Jadavpur University Campus. The 'real life' performance of the instrumentation unit remains to be evaluated and compared with systems which are currently imported.

The impact of socio-economic development on environmental integrity was assessed using for case study a 600 sq km area of the stretch of the Hugli from Bally to Bandel, a thickly populated and industrialised region of West Bengal. Certain problems have been brought to the fore and a pragmatic action plan has been proposed to arrest further deterioration of the environment.

Aspects related to glacier formation and movement at the origin viz., the snow covered Himalayas, could not be initiated as part of the present programme. Among the many incomplete investigations are also those on the enteroviruses and enterophages and their implication in public health. The monitoring for pathogenic bacteria in water has produced results which cast doubts on the hitherto unchallenged position held by the coliforms in quantifying biological pollution. It remains to be seen whether streptococci can be better quantitative indicators of pollution.

The research programme has also led to the enunciation of outline proposals for a few critical studies to be undertaken more intensively. These pertain to the actual operation of the biogeochemical cycles of carbon, nitrogen and phosphorus in the whole network of tributaries and distributaries of the Ganga, the nature of the particulate load carried by the river, the silt deposited, permeation to subsoil aquifers, the sea-land interphase at the estuarine end of the Hugli, the use pattern of pesticides and nitrogenous and phosphatic fertilizers in the basin. More detailed studies on the biology of selected bioindicators may be necessary to design a long term biological monitoring frame work for managing the water resources. Estimates of the particulate load carried by the river are still tentative. It remains now to study the nature and changing pattern of this load and the dynamics of silting and their effect on water flow and contours of the river and its branches. Although many insects inhabiting the basin have been identified, their possible role as vectors of plant diseases and communicable diseases affecting the surging human and animal population of the basin is yet to be uncovered.

Landmarks

Data on the physico-chemical parameters and many aspects of the biotic components of the long stretch of the river has been generated for further refinement. As expected there are wide variations within the stretches. Dissolved oxygen levels excepting in certain problem "pockets" have not depreciated significantly suggesting that with appropriate intervention measures the trend can be reversed. The values for biological oxygen demand also show wide variations depending upon the points of discharge of municipal effluents, the flow of the river as well as the season. Frequent intercomparison of data collected from different stretches revealed deficiencies in the set up for analysis. Steps were initiated to remove these in order to ensure the qualtiy and reliability of the data to be generated in the subsequent phases of the study.

Valuable information on the types of micro flora and micro fauna and the macrophytes forming part of the contiguous ecosystem has been collected over stretches of the river before it touches the plains and during its meandering course across the sub-continent. Some of the trees and shrubs appear to be specific to the Ganga Basin and presumably play vital roles in maintaining the stability of the bank and preventing erosion and flooding. There is an urgent need to group them on sound eco-taxonomical considerations and raise them in nurseries for wide propagation and plantation. A massive programme of such scientifically based tree plantation has to be mounted not only to protect the banks of the river and its branches but also to forestall the adverse impact on climate not unlikely to be triggerred by the setting up of the chain of coal-based super thermal power stations. Cheap sources of energy, solar or natural gas have to be made available to the millions residing in the rural habitations in the basin; community-based biomass plantations of fuel wood from trees native to the basin have to be initiated.

The faunal community consisting of protozoans, crustaceans, rotifers, etc. and the phytoplankton community consisting of Mycophycea, Chlorophyceae and Bacillariophyceae and the benthos have been quantified in some stretches. Evidence has been adduced for the presence of certain aquatic fungi in the pristine stretch of the river even before it enters the plains.

The existing threat of industrial pollution being maximum in the Hugli, information has been collected on the point and non-point sources of pollution due to non-biodegradable chemicals in the stretch from Farraka to Sagar. Attempts have been made to compile statistics of the use of fertilizers and pesticides in some of the stretches in the Basin to explore their possible impact on the quality of water and eventually eutrophication of the estuary.

A scale model of the flow of Ganga for a stretch of 30 km and the confluence of Assi Nala and Ganga has been set up. The model simulates the flow of Ganga in the specific stretch and the discharge of the main sewers into the river and generates for validation of models being developed by computer techniques.

A limited number of abiotic sediments of the river has been collected and qualitatively characterised using geomorphic, geochemical and other techniques. The role of these sediments in the absorption and speciation of toxic heavy metals remains to be elucidated.

With the upper migration of the famous Hilsa fish very much restricted after the construction of the Farraka, efforts have to be made to reinforce the resource of this popular fish in U.P. and Bihar. Studies have been initiated to assess the effects of pollutants on the fish population and their landing for human consumption.

The short-term gains of the University Programme on the Ganga are :

(a) the service rendered by the universities towards the generation of data for water quality assessment and monitoring and as referral centres;
(b) the service rendered by the universities in the generation of scientific information on the biotic life of the Ganga and its role in self-purification; and
(c) the service rendered by the universities in identifying problems for primary and secondary treatment of sewage for recycling the water.

The long-term gains are :–

(a) building an effective science and technology back-support for the Ganga Action Plan and similar plans for cleaning other rivers which are likely to be taken up in the coming years;
(b) training of highly skilled human resources needed in the execution of the various phases of the Ganga Action Plan and their monitoring; and
(c) scientific documentaion of the different aspects of our riverine systems to provide the information back-up to agencies concerned with the management of our major water sheds.

Detailed multi-disciplinary and integrated studies on rivers like the one initiated on the Ganga have become all the more essential in view of :–

(a) periodic episodes of monsoon failure, droughts and less and less flow of water;
(b) periodic episodes of floods affecting the concurrent basins;
(c) plans to use rivers such as the Narmada for multipurpose development schemes with their attendant environmental and ecological problems;
(d) the deterioration of pristine estuarine ecosystems such as the mangroves of the Hugli or Kaveri delta;
(e) the impact of the interphase of estuaries and the bay/sea in affecting coastal fisheries and other marine productivity;
(f) the impact of spread of impounded water of rivers by irrigation canals and their slow drainage or stagnation on disease vector dynamics affecting public health; and
(g) the impact on the reservoir of groundwater of increased human activities including rapid industrial growth on river banks and intensive mono-culture based agricultural activities in the adjacent lands and flood plains.

ANNEXURE 1

No. F-13013/1/82-Adm. I

GOVERNMENT OF INDIA/BHARAT SARKAR
DEPARTMENT OF ENVIRONMENT
(PARYAVARAN BHAVAN)

BIKANER HOUSE
SHAJAHAN ROAD
NEW DELHI-110011

Dated the 31st August, 1982

ORDER

Sub : Constitution of the Working Group for Coordinated Research Projects in the Ganga Basin.

Pursuant to concurrence of the Planning Commission for transferring the funds to the Department of Environment, for coordinated eco-development projects in the Ganga Basin, it has been decided to constitute a Working Group with the following composition :

1.	Dr C.R. Krishna Murti, Director, Industrial Toxicology Research Centre, Lucknow.	Chairman
2.	Dr Nilay Chaudhury, Chairman, Central Board for the Prevention and Control of Water Pollution, New Delhi.	Member
3.	Dr B. B. Sundaresan, Director, National Environmental Engg. Research Institute, Nagpur.	Member
4.	Dr P.G. Adyalkar, Ground Water Board, Calcutta.	Member
5.	Dr K. Sehgal, Central Inland Fisheries Research Institute, Barrackpore, West Bengal.	Member
6.	Prof. Mahatam Singh, Director, Institute of Agriculture, Banaras Hindu University, Varanasi.	Member
7.	Representative of Planning Commission.	Member
8.	Development Commissioner, State Government of Bihar, Patna.	Member
9.	Dr N.L. Ramanathan, Director, Dept. of Environment.	Convenor

2. The terms of reference for the Working Group will be :
   (i) To identify priority project and institutions / agencies / individual scientists for undertaking these projects,
   (ii) To examine the project proposals and to recommend financial support by the Department of Environment,
   (iii) To oversee the implementation of the projects and to suggest mid-term corrections as and when needed, and
   (iv) To collate the major findings/data to be made available through these projects and interactions with the concerned development agencies.

3. The term of the Working Group will be for a period of 3 years from the date of issue of this order.

4. The TA/DA expenses to be incurred by non-official members for attending the meetings of the Working Group will be borne by this Department as per rules admissible.

5. This issues with the approval of Secretary, Department of Environment.

Sd/-
(N.D JAYAL)
JOINT SECRETARY

/True Copy/

Copy of D.O.No.ITRC/DIR/GANGA-83 dated January 3, 1983 from Dr C.R. Krishna Murti, Chairman, Working Group on the Ganga Basin Eco-Development Project, addressed to Vice Chancellors of Universities located on the Ganga Basin.

Dear Vice-Chancellor :

Greetings of the season and wishes for a HAPPY NEW YEAR.

A note on the Working Group on Coordinated Research Projects in the Ganga Basin is enclosed for your kind information. Excerpts from the Planning Commission document "University and Eco-Development" pertaining to the Ganga Basin are also enclosed for your ready reference.

As Chairman of the Working Group on the Ganga Basin Eco-Development Project, I have the pleasure and privilege of soliciting the active participation of your University Scientists in the programme. Dr N.L. Ramanathan, the Member-Secretary and I propose visiting your University in the near future to discuss with your colleagues project proposals in the area of ecological studies in relation to pollution of the Ganga. In the meantime, kindly communicate the name and address of a Senior Scientist/colleague of your University who could be contacted for detailed discussion on the above.

With kind regards,

Sincerely yours,

Sd/-
(C.R. KRISHNA MURTI)

/True Copy/

ANNEXURE 2

PLAN OF ACTION OF THE WORKING GROUP ON THE GANGA BASIN

1. The Working Group on the Ganga Basin would address itself to the environmental problems along the river course and would consider the framework for a coordinated effort by the Universities situated in this basin and concerned scientific and administrative organizations. The Working Group will, after discussion, define the scope, aims and objectives and modalities of funding and monitoring approved programmes. The objective of encouraging interdisciplinary and multi-institutional collaborative studies should be kept in mind while identifying specific problems for study and/or action. The Working Group may also draw up appropriate guidelines for project preparation and submission and for monitoring and evaluation.

2. One of the main concerns is the quality of the water in the rivers which constitute the Ganga Basin. Therefore, a systematic assessment of the water quality, pollution sources and their characteristics along the rivers, the assimilative capacity and the biological productivity of the rivers, sediment and hydrographic studies are necessary, so that appropriate actions to protect the river quality may ensue. Other relevant problems for consideration are :

(a) Bank erosion and measures for protection
(b) Siltation studies
(c) River bank plantation
(d) Wild life status and protection
(e) Socio economic interaction of people with the river
(f) Human settlements on the banks.

3. Two other areas identified earlier by the Planning Commission are concerned with River Navigation and economic exploitation of riverbed in dry months for cultivation of cash crops. However, these are not directly relevant to the Department of Environment. A view may have to be taken for referring these issues to concerned agencies.

4. The question of involving university students in action oriented programmes for eco-development in the Ganga Basin is to be considered and clearly defined programmes formulated.

5. It is proposed to draw up guidelines for preparation of projects on the basis of the discussion at the meeting and invite proposals in the prescribed format from universities in the specific areas of thrust identified by the Group. The Group would then scrutinize the proposals and recommend suitable projects for fund support.

6. It is expected that the processing of proposals could be completed and grants released during the current financial year.

ANNEXURE 3

WORKING GROUP FOR CO-ORDINATED RESEARCH PROJECTS IN THE GANGA BASIN

Note prepared by Department of Environment, Government of India

The Planning Commission, Government of India, has transferred funds to the Department of Environment, Government of India, for the coordinated eco-development project in the Ganga Basin. The Department of Environment has in turn constituted a Working Group with Dr C. R. Krishna Murti, Director, Industrial Toxicology Research Centre, Lucknow, with the following terms of reference:

(i) to identify priority projects and institutions / agencies / individual scientists for undertaking these projects;

(ii) to examine the project proposals and to recommend financial support by the Department of Environment;

(iii) to oversee the implementation of the projects and to suggest mid-term corrections as and when needed; and

(iv) to collate the major findings/data to be made available through these projects and interactions with the concerned development agencies.

The term of the Working Group will be for a period of three years from 31st August, 1982, the date of issue of order No.F-13013/1/82-Adm.I, Government of India, Department of Environment.

The first meeting of the Working Group took place on Friday, December 31, 1982 at New Delhi. A number of important issues emerged at this meeting, the implications of which for the implementation of the project as a whole will be communicated to you in due course. The Working Group had the opportunity to discuss in some depth one aspect of the Ecosystem development programme, namely, pollution of water in the Ganga Basin based on a background paper submitted by Dr Nilay Chaudhury, Chairman, Central Board for the Prevention and Control of Water Pollution and an integrated project proposal on the theme submitted by National Environmental Engineering Research Institute, Nagpur.

The most significant facts that stood out were the following:

(i) the main locations of high pollution have been identified,

(ii) the major part of the river stream in Bihar is still polluted,

(iii) excepting for the major locations of pollution, the water quality as measured by 45 monitoring stations based on 18 criteria is still satisfactory,

(iv) even in locations of high pollution there are indications that the biota and other yet un-identified factors do contribute to the mitigation of pollution and restoration of the quality of water.

The Working Group felt that Universities can play an effective role in R & D work in :

(a) identifying the biota and factors at present contributing to the 'rehabilitation' of the polluted water,

(b) in maintaining quality control of the data on pollution by developing capabilities in analytical work,

(c) in interpreting the data and building mathematical and other models, and

(d) feeding the expertise back to implementing agencies such as the Central Board of Pollution Prevention and Control.

It was also appreciated that the Universities may not be interested in routine activities such as monitoring pollution. However, to provide training and stimulate the interest of students in such a vital subject as water quality and water management, it was agreed that an integrated R&D project on the status of pollution of the Ganga could be prepared making ample provision for some of the Universities to contribute effectively towards the objectives laid down by the Planning Commission.

ANNEXURE 4

BRIEF BACKGROUND NOTE ON THE GANGA BASIN PREPARED BY THE CENTRAL BOARD FOR PREVENTION AND CONTROL OF WATER POLLUTION

There are as many as 14 major rivers in India, each having a drainage basin measuring more than 20,000 sq km. The annual average discharge of all the 14 rivers is assessed as 1,406 × $10^9 m^3$. These natural waters are being utilized for various competing and conflicting activities like, agriculture, irrigation, livestock, human settlements, industrialization, power production etc. Such human and developmental activities are the potential factors which signifcantly contribute to the pollutional loads in the basins. Hence the aim should be to restore and maintain the waters at various places to such qualities as are needed for the best of their utility. Accordingly, the Central Board for the Prevention and Control of Water Pollution has framed a long term objective of evolution of river basin-wise pollution control programme.

MEASURES

The measures required to plan pollution control on the basis of the above mentioned long term objective are:

1. Classification and zoning of river waters of the country based on their designated best uses;
2. Monitoring of water quality to ascertain the water quality status in a 3-tier grid system; and
3. Evaluation of pollution potential in the river basin.

Any stretch or reach of the rivers is subjected to multiple uses. Among these uses one use would demand the highest quality of water and that stretch or reach is designated by that best use. A quality criteria is assigned to every use. Thus the classification and zoning of the rivers at various reaches help in identifying the water quality objective of various reaches of the rivers.

Superimposition of water quality map on water use map indicates the stretches of the river where existing quality is inferior to the desired quality and warrants prevention and control of pollution. The water quality map of the river can be prepared based on the data collected by continuous monitoring of water quality at different stations.

STATUS OF THE GANGA WATER QUALITY MONITORING STUDY

With the above mentioned long term objective, the Central Board undertook the task of the river basin-wise pollution potential assessment and the compiled information would be disseminated through the Assessment and Development Study of River Basin Series (ADSORBS). To start with this task Central Board conducted a pilot study on the Yamuna sub-basin, the report of which is available with a title, "Basin Sub-basin Inventory of water pollution. The Ganga Basin, Part I: The Yamuna sub-basin" (ADSORBS/2/1980-81). After gaining requisite experience in such a study, the Central Board launched a project on the entire Ganga Basin, excluding the Yamuna sub-basin. The first phase of the project comprised of monitoring of the Ganga water at 45 stations covering the states of Uttar Pradesh, Bihar, West Bengal and Madhya Pradesh. In Uttar Pradesh, 21 stations were identified for the monitoring study. In Bihar 11 stations, in West Bengal 9 stations, and in Madhya Pradesh 4 stations were selected. The list of the monitoring stations is given in Table 1.

After a careful evaluation, a set of 19 basic parameters depicting physical, chemical and bacteriological quality of the river waters is adopted for the analysis. The list of the selected parameters is given in Table 2.

On the basis of the monitoring data the water quality profile of two calendar years of 1980 and 1981 is compiled for the Ganga riverine systems excluding the Yamuna systems. The profile which indicates the degree of pollution at various stretches of the river was identified.

Data on Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) obtained from 39 stations during the period of May 1980 - March 1981, are represented in Table 3. The water quality of the Ganga is best in the State of Bihar. Excluding the location below the city of Calcutta, the Ganga water quality in the State of West Bengal is also persistantly better. In Uttar Pradesh the BOD of water ranges between 3 and 30 mg/l at a point immediately below Kannauj and the DO value drops down to 5 mg/l. Within 20 km below Kannauj the BOD decreases to 2 mg/l and the DO increases to 8 mg/l till Kanpur is reached. The three monitoring stations of Kanpur (Sarasaiya Ghat, Bhagatdas Ghat and Kanpur downstream station) in the stretch of the Ganga, receiving the city wastes directly, again show the BOD value ranging between 10 and 55 mg/l and the DO between 4 and 6 mg/l. Within 50 km from Kanpur at a place called Dalmau the BOD ranges between 2.3 and 4.5 mg/l and the DO increases to 8 mg/l. This is repeated below Allahabad, Varanasi, Patna and finally Calcutta. Based on the BOD-DO profile the stretches of the Ganga are designated with various degrees of pollution. It needs no elucidation that city sewage is the major cause for such a reach-wise pollution (Table 1).

Still a large amount of the monitoring data is being processed by the Central Board, after completion of which water quality map of the Ganga Basin can be drawn. The data on land use and irrigation, pesticide and fertilizer consumption, pollutional load generation and discharges etc., are collected and compiled. The final report entitled "Basin Sub-basin Inventory of water pollution - The Ganga Basin, Part II", covering the entire Ganga Basin excluding the Yamuna sub-basin would be ready by March 1983.

With a view to evaluate pollution potential in the river basin the information has been collected from block level, compiled and arranged at district level and the complete information is presented in 4 maps as detailed below:

Map 1 : Land Use - Agriculture (including Forestry and Orchards)

The map contains (1) percentage cultivable to total land; (2) percentage gross sown to cultivable land; and (3) fertilizer expressed in Nitrogen, Phosphorus and Potassium.

Map 2 : Land Use - Irrigation

The map contains (1) percentage net irrigated to net sown land; (2) percentage net canal irrigated to net irrigated land; and (3) pesticides input in Organochlorine, Organophosphorus and other groups (expressed as active percentage).

Map 3 : Human Settlements

The map contains (1) Urban and rural population; (2) water consumed and wastewater generated, (3) cattle population; (4) pollutional load from human settlements and industries; and (5) toxic pollutional load from industries.

Map 4 : Riverine Systems

The map contains (1) classification and zoning of the river; (2) runoff at significant locations; (3) rainfall and (4) entry points of significant pollutional loads. This map would contain the water quality data when that will be available.

The monitoring of the water quality at the 45 stations is a continuous programme.

TABLE 1

List of Monitoring Stations in the River Ganga

UTTAR PRADESH

1. Rishikesh
2. Haridwar
3. Garhmukteshwar
4. Katchla Bridge
5. Kannauj
6. Upstream of Kanpur
7. Sarasaiya Ghat, Kanpur
8. Bhagatdas Ghat, Kanpur
9. Downstream of Kanpur
10. Dalmau
11. Upstream of Allahabad
12. Nagbasuki Temple, Allahabad
13. Sheokuti, Allahabad
14. Downstream of Allahabad
15. Mejo Road on-R. Tons
16. Mirzapur
17. Upstream of Varanasi
18. D. Ghat, Varanasi
19. Sindhi Ghat, Varanasi
20. Downstream of Varanasi
21. Trighat

BIHAR

22. Buxar
23. Khurji, Patna
24. Darbhanga Ghat, Patna
25. Ganga Bridge, Patna
26. Sultanpur
27. Barhaiya
28. Monghyr
29. Bhagalpur
30. Colgong
31. Rajmahal
32. Koelwar on R. Son

WEST BENGAL

33. Farakka
34. Baharampur
35. Katwa
36. Nabadwip
37. Kalyani
38. Palta
39. Dakshineshwar
40. Uluberiya
41. Diamond Harbour

MADHYA PRADESH

42. Chachai on R. Son
43. Madav Garh on R. Tons
44. Deora on R. Son
45. Chakghat on R. Tons

TABLE 2
List of Parameters for Analysis of Water Quality

A PHYSICAL
1. Temperature
2. Turbidity
3. Velocity of Flow

B CHEMICAL
1. *p*H
2. Dissolved Oxygen
3. Biochemical Oxygen Demand
4. Total Kjeldahl Nitrogen (Ammonia Nitrogen + Organic Nitrogen)
5. Nitrogen (Nitrate + Nitrite)
6. Conductivity
7. Chloride
8. Hardness
9. Calcium
10. Magnesium
11. Alkalinity
12. Sulphate
13. Sodium
14. Chemical Oxygen Demand

C BACTERIOLOGICAL
1. Total Coliform (MPN)
2. Fecal Coliform (MPN)

TABLE 3
Water Quality of the River Ganga (between May, 1980 and March, 1981)

Sl. No.	Sampling Location	Dissolved Oxygen mg/l		Biochemical Oxygen Demand mg/l
BEST CLEAN RANGE				
1.	Rishikesh	9	Clean	less than 2
2.	Haridwar	9		less than 2
3.	Garhmukteshwar	8		about 2
4.	Katchla Bridge	9		about 2
5a.	Kannauj Upstream	8		2.0
5b.	Kannauj Downstream	5	Second Polluted	3 to 30
5c.	Further below Kannauj (20 km below)	8	Clean	about 2
6.	Upstream of Kanpur	8		about 3
KANPUR				
7.	Sarasaiya Ghat, Kanpur	5	Most Polluted	10 and above
8.	Bhagatdas Ghat, Kanpur	6		15 to 30
9.	Kanpur Downstream	4		30 to 55
10.	Dalmau (50 km below Kanpur)	8	Clean	2.3 to 4.5
ALLAHABAD				
11.	Allahabad Upstream	8	Third Polluted	5 to 14
12.	Nagbasuki Temple, Allahabad	8		6 to 14
13.	Sheokuti, Allahabad	8		4 to 12
14.	Allahabad Downstream	8		6 to 14
15.	Mirzapur (50 km below Allahabad)	8.5	Clean	about 4
VARANASI				
16.	Varanasi Upstream	8	Second Polluted	4 to 9
17.	D. Ghat, Varanasi	8		5 to 7 s
18.	Sindhi Ghat, Varanasi	8	Second Polluted	5 to 24
19.	Varanasi Downstream	7		5 to 7
20.	Trighat (UP-Bihar Border)	9	Clean	about 4
21.	Buxar	9		less than 2
22.	Khurji, Patna Upstream	8	Slightly Polluted	about 3
23.	Darbhanga Ghat, Patna	7		2 to 7
24.	Ganga Bridge, Patna Downstream	7		2 to 7
25.	Sultanpur (15 km below Patna)	8		less than 2
26.	Barhaiya	9		less than 2
27.	Monghyr	8		less than 2
28.	Bhagalpur	8		less than 2
29.	Colgong	8		less than 2
30.	Rajmahal (Bihar-West Bengal Border)	8		less than 2
31.	Farakka	7		less than 2
32.	Baharampur	7		less than 2
33.	Katwa	7		less than 2
34.	Nabadwip	7		less than 2
35.	Kalyani	7		less than 2
CALCUTTA				
36.	Palta, Calcutta Upstream	4 to 7		about 2
37.	Dakshineshwar	5 to 7		about 4
38.	Uluberiya	4 to 8	Most Polluted	4 to 10
39.	Diamond Harbour	3 to 6		10 to 50

ANNEXURE 5

A NOTE ON STANDARD METHODOLOGY FOR ANALYSIS OF WATER SAMPLES OF THE GANGA

A major multi-disciplinary and coordinated project on the Ganga Basin Ecosystem Development involving almost all the universities located on the banks of the Ganga and its vicinity is being currently funded by the Department of Environment, Government of India.

Phase I of the programme envisages detailed studies on stretches of the Ganga from its upper tract as it enters the plains through the middle tract to the deltaic estuarine region in West Bengal. The studies are related to fauna and flora, existing levels of biological and chemical pollution in vulnerable regions and the manner in which regeneration takes place. One of the main emphasis in Phase I is on the assessment of the quality of water of the Ganga and how it affects the floristic and faunistic wealth of the ecosystems sustained by it.

During discussions with the Vice-Chancellors of the Universities participating in the programme and the Scientists identified by them who will be conducting the studies, it was agreed that, as far as feasible, uniform and identical analytical techniques will be used for sampling of water and its analysis.

This note is an attempt to give in a summarized form the guiding principles and the methods for water analysis to be adopted by all the investigators. Since the complete study of the biogeochemistry of the Ganga should eventually become part of the Project, the method to be used is applicable to measurement of C, N, P and S cycles in addition to metals. In assessing pollutant load we may have to keep in mind toxic metals and organics arising out of biological pollution as well as those being discharged through untreated or partially treated industrial effluents.

2. PARAMETERS TO BE STUDIED

For metal and metalloid cycling

(a) in the dissolved phase :

Sodium, Potassium, Calcium, Magnesium, Arsenic, Cadmium, Lead, Mercury, Zinc, Copper, Chromium, Manganese, Iron, Nickel (The first four by Flame Photometer if available and rest by Atomic Absorption Spectrophotometer).

(b) in the particulate matter:

Magnesium, Aluminium, Silicon, Phosphorus, Sulphur, Potassium, Calcium, Manganese, Iron, Nickel, Copper, Chromium, Mercury.

For *carbon cycling* the following parameters are suggested:

- Dissolved organic carbon - Sugars, Carbohydrates, Proteins, amino acids
- Dissolved inorganic carbon – HCO_3”
- Particulate organic carbon.

For *nitrogen cycling* the following parameters are suggested:

- Amino Acids (dissolved, particulate)
- Particulate organic nitrogen.

For *phosphorus cycling* the following parameters are suggested:

- Dissolved phosphate
- Particulate phosphorus

For *sulphur cycling* the following parameters are suggested:

- Dissolved sulphates
- Particulate sulphates
- Pollutant load - organics, phenolics, detergents, pesticides, toxic metals.

3. SAMPLING

Kindly remember that the flux of materials transported by the rivers is influenced by many factors. Rivers, in general, are not well mixed horizontally and vertically and as such one cannot avoid wide variations when samples are collected at the surface or at other points across the river. Generally surface samples show concentrations only half that obtained through depth integrated sampling.

For large rivers monthly or bimonthly samples are usually adequate to determine relations between concentrations, flow and seasonal trends.

In your sampling programme it is essential to select the sampling points. You could check the homogeneity at a chosen sampling location by measuring Eh or total suspended load. In order to obtain a representative sample you could collect individual subsamples at different points and mix them. If the velocity and the depth profiles of the river are available, the subsamples could be weighed according to the volume of the flow they represent. If a depth and velocity integrating sampler such as the Elbe type is available, please use it for collection of representative samples.

4. FILTRATION

Keeping in mind recent advances in the field of analytical chemistry, it is preferable to attempt to separate the dissolved constituents from the particulates and analyse the two separately for inorganic and organic constituents. Although there is little information on the effect of filtration on the subsequent analysis, it is suggested that all samples are filtered through a membrane either using a syringe or simple suction. Filtrates are used for different field and laboratory measurements. Filters are air dried and depending on the analysis to be conducted extracted with appropriate solvents for organic C + N or wet ashed in case of assay for inorganics. The membrane recommended is 0.45 μm filter or precombusted glass fibre filter. These are manufactured by Schleicher and Schull, FRG or Whatman, U.K.

5. MEASUREMENTS

A general scheme for separation of particulates is shown in Table 4. A short description of the analytical procedures is given in Table 5.

It is a good practice to include routinely the following in field measurements : temperature, *p*H and Eh, conductivity, alkalinity, chloride content, total hardness and dissolved oxygen.

The parameters for laboratory measurements are decided prior to starting the programme. The same sample can be used for phosphate, silica, nitrate, metals, particulate organic carbon, particulate organic nitrogen and metallic elements by different analytical procedures.

6. ATOMIC ABSORPTIOMETRY

Filtrates are preserved with 2-3 drops of conc. HCl for every 250 ml filtrate. Standards are prepared from commercially available chemicals (Merck, Fischer etc.) Depending upon the instrument used, presetting and other conditions are employed to quantify the element analysed. Most of the available (commercially) instruments can be programmed and results printed out.

7. PARTICULATES

Particulates can be subjected to microscopic analysis of 0.45 μm membrane collected material by :

(a) Scanning electron microscope for morphology

(b) EDAX, Atomic Absorption Spectroscopy or Neutron Activation Analysis for elemental composition,

(c) X-ray diffraction for crystalline nature.

Particulate organic carbon and nitrogen consist mainly of proteins, polysaccharides and lipids. Individual amino acids and carbohydrates can be characterized when needed.

8. CYCLING OF C AND N

Total dissolved carbon (organic and inorganic) is determined by wet oxidation with persulphate or high combustion and converting CO_2 to methane, which is detected by Flame Ionisation Detector in a Gas Liquid Chromatograph. In any comprehensive study on carbon cycling, dissolved total carbohydrate, dissolved free carbohydrate, suspended total carbohydrate, dissolved total amino acids, dissolved free amino acids, suspended total amino acids must all be accounted for.

9. RECORD KEEPING FOR INFORMATION STORAGE AND RETRIEVAL

It is recommended that a uniform card system be used for recording the analytical data to enable the feeding of the same to a central storage system subsequently. It is, therefore, necessary to have codes for numbers and parameters and symbols for the appropriate language to be used in the logistics of the information storage and retrieval system deployed for the work.

TABLE 4

Scheme for Study of Quality of the River Water

Field	Laboratory	
Temperature	Membrane Filter or Glass Fibre Filter	
*p*H, Eh		
Conductivity	*Filter*	*Filtrate*
Alkalinity	* Suspended matter	* Dissolved matter
Dissolved Oxygen	* Metals	* Silicate
Total hardness	* Organic Particulates	* Nitrates
Chloride	* Microscopic Examination	* Sulphate
		* Metals

TABLE 5
Analytical Procedures for the River Water (Summary)

Parameter	Technique	Parameter	Technique
Suspended Matter	0.45 μm membrane filter or glass fibre filter	Dissolved O_2	Winkler titration
*p*H / Eh	Portable meter. Combined glass electrode	Si O_2	Colorimetric / molybdenum blue reaction
Conductivity	Portable meter. Correct values to a common temperature	PO_4^{-3} (ortho)	Colorimetric with ammonium molybdate and antimonyl tartrate / reduction by ascorbic acid
Cl^-	Titration with $AgNO_3$		
Total hardness	Titration with EDTA	NO_3^-	Copper Cadmium reduction to nitrite, reaction with sulfanilamide and N - I - naphthyl - ethylene - diamine
HCO_3^-	Calculated from t-alkalinity (H_2SO_4 to *p*H 4.5),		
	and p-alkalinity (H_2SO_4 to *p*H 8.3)	Metals dissolved	Atomic Absorptiometry or
Alkalinity	Titration with H_2SO_4	Metals particulate	EDAX Analysis / Neutron Activation

ANNEXURE 6

No. J - 39016/1/86-GPD Dated the1st December, 1986

OFFICE MEMORANDUM

Subject : Reconstitution of the Working Group on Integrated Action Oriented Research on the River Ganga.

1. **Background & Objective**

The Planning Commission had initiated the coordinated eco-development projects on the Ganga through a network of universities located on the river stretch from Narora to Calcutta. The project was later transferred to the Department of Environment for managing the programme. A Working Group under the Chairmanship of Dr C.R. Krishna Murti with eight other members was constituted on August 31, 1982 for a term of three years. While reviewing the programme recently it transpired that the stretch of the river from Narora to Allahabad had not been taken up so far and the universities already identified for work on this stretch would take three more years to complete the studies and would also require continued evaluation and guidance. The fourteen universities which have initiated their studies between 1983-84 are expected to complete the studies by 1987. It is, therefore, necessary that the studies of these universities and the results are synthesized in order to obtain a chemical, physical and biological profile of the river.

2. Accordingly the Working Group is hereby reconstituted with the following membership :

(1) Dr C.R. Krishna Murti, Chairman, Scientific Commission for Continuing Studies on Effects of Bhopal Gas Leakage on Life Systems, Cabinet Secretariat, Sardar Patel Bhavan, New Delhi – Chairman

(2) Dr K. S. Bilgrami, Professor of Botany, Bhagalpur University, Bihar.

(3) Dr R.P. Mathur, Prof of Civil Engineering, University of Roorkee, Roorkee, Uttar Pradesh.

(4) Dr T.M. Das, Life Science Centre, Calcutta University, 35, Ballygunge Circular Road, Calcutta-700 019.

(5) Dr K.R. Ranganathan, Director (Technical), Ganga Project Directorate, Shahjahan Road, New Delhi-110 011

3. **Terms of Reference**

The terms of reference for the Working Group will be as follows :

(i) To review the ongoing research work under the integrated action oriented research project on the fourteen universities and the work to be taken up in the Narora-Allahabad stretch.

(ii) To set guidelines for preparation of a comprehensive report incorporating all the scientific works carried out and to be completed by 1987 and shortly thereafter by the fourteen universities.

(iii) To get the report prepared as per the guidelines by March 31,1988. The report will form the basis for future biological conservation and biomonitoring schemes which may be taken up under the appropriate plan.

(iv) The term of the Working Group will be for a period not exceeding two years from the date of issue of this memorandum.

4. The Working Group is expected to normally meet in New Delhi; but may also outside New Delhi as and when considered necessary.

5. The Working Group may invite experts/outsiders to attend the meeting.

6. The non-official members including invitees will be eniltled to the payment of TA/DA as per Rules.

The expenditure on supporting staff and services will be borne by the Department of Environment, Forest & Wildlife. The Chairman may engage the services of suitable personnel for such duration as may be considered fit, not exceeding one year. They will be engaged purely on an ad-hoc and temporary basis and the Department of Environment, Forest and Wild Life will not have any responsibility for continuity of services or employment. It is noted that the services of Research Assistant/Associates and a typist may be required and the total monthly expenditure will not exceed about Rs. 4,500. The appropriate amount will be payable from the date of engagement of the personnel and will be paid to the Chairman of the Working Group.

7. The expenditure incurred on the Working Group will be debitable to the Major Head '279-A' - Scientific Research A2(1) - Assistance to other scientific bodies, A2(1)(1) - Ecological & Environmental Research, A2(1)(1)(2) - Eco-development Programme, A2(1)(1)(2)(5) - Integrated Action Oriented Research, Development and Extension Projects under Demand No.27 - Environment during 1986-87 (Plan).

8. This issues with the approval of the Project Director, Central Ganga Authority and Additional Secretary, Ministry of Environment & Forests.

Sd/-
(D. CHAKRABARTI)
DEPUTY SECRETARY TO THE GOVERNMENT OF INDIA

(1) Dr C.R. Krishna Murti, Chairman, Scientific Commission for Continuing Studies on Effects of Bhopal Gas Leakage on Life Systems, Cabinet Secretariat, Sardar Patel Bhavan, New Delhi.

(2) Dr K.S Bilgrami, Professor of Botany, Bhagalpur University, Bhagalpur, Bihar.

(3) Dr R.P Mathur, Professor of Civil Engineering, University of Roorkee, Roorkee, Uttar Pradesh

(4) Dr T.M. Das, Life Science Centre, Calcutta University, 35 Ballygunge Circular Road, Calcutta-700 019.

(5) Dr K.R. Ranganathan, Director (Technical), Ganga Project Directorate, Kota House Hutments, Shahjahan Road, New Delhi-110 011.

Copy forwarded for information and necessary action to :

(1) The Pay & Accounts Officer, Ministry of Environment & Forests, 'Paryavaran Bhavan', CGO Complex, II Phase, Lodhi Road, New Delhi-110 003

(2) The Drawing & Disbursing Officer, Department of Environment, Forests & Wild Life, Paryavaran Bhavan, CGO Complex, II Phase, Lodhi Road, New Delhi-110 003

(3) P S to Secretary, Ministry of Environment & Forests, Bikaner House, Shahjahan Road, New Delhi-110 011.

(4) P S to P D & A S, Ganga Project Directorate, Kota House Hutments, Shahjahan Road, New Delhi-110 011

(5) The Joint Secretary (Admn), Ministry of Environment & Forests, Paryavaran Bhavan, CGO Complex, II Phase, Lodhi Road, New Delhi-110 003.

(6) The Deputy Secretary (Admn) Ministry of Environment & Forests, Paryavaran Bhavan, CGO Complex, II Phase, Lodhi Road, New Delhi - 110 003

(7) The Vice Chancellor, Bhagalpur University, Bhagalpur, Bihar

(8) The Vice Chancellor, University of Roorkee, Roorkee, Uttar Pradesh

(9) The Vice Chancellor, University of Calcutta, College Street, Calcutta

(10) Mr M Parabrahmam, Director (RE), Deptt of Environment, Forests & Wildlife, Paryavaran Bhavan, CGO Complex, II Phase, Lodhi Road, New Delhi-110 003

(11) Mr R Anandakumar, P S O, Deptt. of Environment, Forests & Wildlife, Paryavaran Bhavan, CGO Complex, II Phase, Lodhi Road, New Delhi-110 003

Sd/-
(D. CHAKRABARTI)
DEPUTY SECRETARY TO THE GOVERNMENT OF INDIA

ANNEXURE 7

INSTITUTIONS WHICH PARTICIPATED IN THE STUDY

Sl. No.	Name of the Institution	Title of Project and Stretch of the river	Principal Investigator	*Page*
1.	Garhwal Univ. Srinagar, Garhwal	Pollution Study of the Upper Ganga and its tributaries. (Gangotri to Rishikesh)	Prof H. R. Singh	226
2.	Gurukul Kangri Viswavidyalaya, Haridwar	Integrated study of the river Ganga. (Rishikesh to Garhmukteshwar)	Dr V. Shankar	226
3.	University of Roorkee, Roorkee	Pollution modelling of the Upper Ganga Basin. (Garhmukteshwar to Narora)	Dr R. P. Mathur	227
4	Aligarh Muslim University, Aligarh	Integrated study of the Ganga Ecosystem between Narora and Kannauj – (a) General water quality measurement. (b) Taxonomical studies of bacteria. (c) Man-river interaction studies from land use : Geographic points of view. (d) Pesticides and radioactivity in the river water.	Prof A. M. Siddiqi	227
5.	University of Kanpur, Kanpur			
(i)	D.B.S College, Kanpur	Physico-chemical studies of the Ganga water from Kannauj to Shuklaganj.	Dr U. K. Pandey	228
(ii)	Christ Church College, Kanpur	Biological studies of the Ganga Ecosystem between Kannauj and Shuklaganj.	Dr A. C. Shukla	228
(iii)	Feroze Gandhi College, Rae Bareli	(a) A comprehensive study of the Ganga and its dependents. (b) Environmental awareness programme. (Kalakankar to Phaphamau)	Dr A. K. Sinha	228
6.	Banaras Hindu University, Varanasi	(a) Plant population, community structures and function of riparian and aquatic macrophytes in relation to pollution of the river Ganga.	Dr R. S. Ambasht	229
		(b) Physico-chemical and biological characterization of the river Ganga in relation to Pollution.	Dr B. D. Tripathi	230
		(c) Physico-chemical and physiological assessment of heavy metal pollution in the river Ganga.	Dr L. C. Rai	230
		(d) Pollution of the river Ganga with heavy toxic metals.	Dr D. C. Rupainwar	230
		(e) Coordinated study of the river Ganga : Civil Engineering aspects.	Dr U. K. Choudhary	231
		(f) Coordinated study of the river Ganga : Study of the river water pollution at Varanasi and prevalence of gastro intestinal morbidities.	Dr I. C. Tiwari and Dr P. C. Sen	232

(*Contd.*)

ANNEXURE 7

Sl. No.	Name of the Institution	Title of Project and Stretch of the river	Principal Investigator	Page
		(g) Hydrogeological study regarding the pollution of the river Ganga. (Hydrogeological aspects).	Dr G. C. Chowdhary	232
		(h) A study of the submerged and aquatic plants of medicinal and anti-pollutant value in reference to the Ganga water pollution.	Dr R. H. Singh	232
		(i) Role of sediment in attenuation of trace metals in polluted aquatic environment of the river Ganga: Sedimentological aspects.	Dr M. N. Mehrotra	233
		(j) Impact of heavy metal pollution in the river Ganga on fish.	Dr A . K. Mittal	234
		(k) Water pollution and endocrine imbalance with special reference to high thyroid physiology and reproduction in some important food fishes.	Dr T. P. Singh	234
		(l) A study of the river Ganga with reference to environmental and socio-economic awareness (extension activities).	Dr Krishna Bahadur	234
		(m) Coordinated study of the river Ganga (agricultural aspects) Mirzapur to Ballia.	Dr R. C. Tiwari	235
7.	Patna University, Patna	An inter-disciplinary study on the problems of water pollution of the river Ganga with special reference to identifying biota and their role in rehabilitating the river water, sedimentation and specification studies, data generation, collation, analysis and mathematical modelling of the river quality and carbon cycling. (Buxar to Barauni)	Dr R. K. Sharan	236
8.	Rajendra Agricultural University, Samastipur	Coordinated study of the Ganga Ecosystem from Patna to Barauni. (Barh to Sultanganj)	Dr A. K. Srivastava	237
9.	Bhagalpur Univ., Bhagalpur	Study of the river Ganga from Monghyr to Farakka. (Barauni to Farakka)	Dr K. S. Bilgrami	238
10.	University of Kalyani, Kalyani	(a) Biotic Communities and productivity of the river Ganga and its bunds as affected by pollution.	Prof K. R. Samaddar	239
		(b) Bio-ecological studies of the river Ganga with special emphasis on various aspects of the river fauna as affected by pollutants and restoration of normal faunistic pattern.	Dr S. P. Bhattacharya	239
		(c) Physico-chemical studies of the river Ganga for the rehabilitation of the polluted water and development of analytical methods. (Katwa to Naihati)	Prof R. Sengupta	240
11.	University of Calcutta, Calcutta	(a) Socio-economic maladies created by deteriorating hydro-fluvial region of the Ganga and to suggest measures for their amelioration.	Prof K. G. Bagchi	240
		(b) Survey of Agro-chemicals (fertilizers, pesticides etc.) in the riverine land and its impact on the level of pollution of the Ganga water.	Prof T. M. Das	240
		(c) Awareness programme. (Bally to Bandel)	Prof T. M. Das	240

(*Contd.*)

ANNEXURE 7

Sl. No.	Name of the Institution	Title of Project and Stretch of the river	Principal Investigator	Page
		(d) Effect of pollution on biological health of the Ganga water and devising remedial measures.	Prof N. C. Datta	241
12.	Burdwan Univ., Burdwan	(a) Characterization of pollutants in the Ganga water.	Prof J. Das	241
		(b) Mathematical and statistical analysis of the problems of pollution, erosion, ecology of aquatic population.	Prof S. K. Chakravarty	241
		(c) Effects of polluted Ganga water on micro and macroflora in the river and its adjoining areas and biological control of pollution.	Prof A. K. Banerjee	242
		(d) Harnessing of riverine resources with reference to commercially viable fish species. (Behrampur to Katwa)	Prof D. K. Choudhuri	242
		(e) Effects of pollutants of the Ganga on the embryonic and post-embryonic development of some aquatic and terrestrial animals at the cellular/sub-cellular levels.	Prof J. N. Medda	242
		(f) Interactions between zooparasitic nematodes and vertebrate hosts inhabiting the polluted bodies of water of the river Ganga.	Dr G. Majumdar	243
		(g) Studies on the impact of irrigation and flooding by the polluted Ganga water on the soil fauna of cultivated and uncultivated soils (fields) in relation to fertilizers and productivity of soil.	Prof D. K. Choudhuri	243
		(h) Utilization of human resource : Problems and Suggestions (with four subprojects) Behrampur to Katwa.	Dr M. R. Choudhury	243
13.	Bidhan Chandra Krishi Viswavidyalaya, Kalyani	(a) Awareness Programme Workshop.	Dr S. Mukhopadhyay	244
		(b) (i) Natural properties, transformation of the river sediment, and its nutritive value.		
		(ii) Effect of run off pesticides on the water quality.		
		(c) (i) Microbiology of the polluted water of Hugli.		
		(ii) Role of the Ganga in Epidemiology.		
		(iii) Biological Monitoring of the water quality of Hugli.		
		(iv) Utilization of fungi for biopurification.		
		(d) Propagation of horticultural plants for the conservation of the banks of Hugli river.	Dr P. G. Maity	244
		(e) Effect of pollution due to saline tidal water on the ecosystem of the deltaic region and its solution. (Katwa to Bandel)	Dr A.K. Mukhopadhyay	245
14.	Jadavpur Univ. Calcutta.	Environmental Awareness Programme Workshop.	Prof Dilip Bose	245
		Instrumentation for pollution monitoring of the Hugli Estuary.	Prof P. Som	245

Title of the Project : **Pollution Study of the Upper Ganga and its tributaries. (Gangotri to Rishikesh)**

Principal Investigator : PROF H. R. SINGH, Garhwal University, Srinagar, Garhwal.

Termination Date : 31st March, 1988

Objectives :

(i) To conduct physico-chemical and biological monitoring of the river from Gangotri to Rishikesh.

(ii) To assess water quality and changes, if any, with the downward flow of the river and the causes thereof.

(iii) To find the impact of human activity on the quality of the river water.

(iv) To gain preliminary information in respect of the vegetation and geological and geographical features of the river basin in order to obtain a comprehensive picture of the functioning of the riverine system as a whole.

Highlights of the Results

(i) Silt load forms a major problem in the Upper Ganga due to various activities such as deforestation, landslides, slope failures and construction activities.

(ii) Noteworthy industrial pollution was absent. However, a large number of small scale industries do generate solid/liquid wastes.

(iii) Unhygenic conditions prevailed along the river banks at Uttarkashi.

(iv) The level of BOD was higher during summer (4.46 mg/l) than in winter (3.51 mg/l) and lowest in monsoon (3.09 mg/l). DO levels were generally high.

(v) Presence of organic load was confirmed by the indicator organisms like *Navicula, Cyclotella. Nitzschia, Synedra, Chironomus, Tabanus* and ciliates. *Cymbella, Achanthes, Dixa* and other clean water forms were also present.

(vi) High turbidity was responsible for the absence of clear water species like Cladophora (present in Alaknanda) and the presence of *Stigeoclonium* indicated higher concentrations of heavy metals e.g. Pb, Cd. etc.

(vii) Creation of huge barriers across the mainstream to harness the water for power generation has resulted in blockade of the passage for migration of fish to their breeding grounds and thus resulting in large scale depletion of fish between Rishikesh and Haridwar especially endangered valuable species like Mahseer.

Title of the Project : **Integrated Study on the river Ganga. (Rishikesh to Garhmukteshwar)**

Principal Investigator : DR V. SHANKAR, Gurukul Kangri Viswavidyalaya, Haridwar

Termination Date : October 30, 1987 (Extended for submission of report up to December, 1987).

Objectives :

(i) Preparation of inventory of flora and fauna including phytoplankton and zooplankton of the region.

(ii) Identification of the nature and sources of pollution of the Ganga and of the causes of degradation of the soil and also siltation and floods and devising methods to check them.

(iii) Selection of suitable plant species for the river bank plantation to check erosion.

(iv) A complete chart of the physico-chemical and biological characters of the identified zone on monthly basis.

(v) To make attempt to identify the biological indicators of river pollution and to understand the role of phyto and zooplankton in purification of water.

Highlights of the Results

(i) The sediment load of the Ganga is very high being 1.5 billion tons per year and the only solution for reducing or controlling the same lies in heavy tree plantation.

(ii) The major culprits who pollute the Ganga in the upstream are Saraswati Nala, IDPL Nala, BHEL - Jwalapur Nala, Vam Organics, Gajroula and a few storm water and domestic waste water chemicals.

(iii) The construction of barrages at Rishikesh and Bijnor (Pashulok barrage, Rawali barrage) has resulted in ecological disturbance leading to seepage, flood and water logging.

(iv) Research on the following may be initiated–
  (a) Studies on the effect of heavy metals on the morphology of algal flora of the Ganga.
  (b) Degradation of complex organic compounds by soil fungi.

Title of the Project : **Pollution modelling of the Upper Ganga Basin. (Garhmukteshwar to Narora)**

Principal Investigator : PROF R. P. MATHUR, University of Roorkee, Roorkee.

Termination Date : 31st March, 1988

Objectives : (i) To generate and store authentic background data pertaining to the Ganga ecosystem viz. the river hydrology, river quality, catchment activity and characteristics.

(ii) Apply systems analysis techniques for getting some insight into the ecosystem for its efficient management. This involved development of a mathematical model to study the water quality of the river by finding out :
  (a) Water quality index for current and designated best use,
  (b) Impact of variation in the river discharge on water quality.

(iii) Projecting a clear picture of the state and extent of pollution of the Ganga ecosystem vis-a-vis the reasons and suggesting remedies.

Highlights of the Results (i) The physico-chemical characteristics of tributaries of the river Ganga in the Upper Ganga Region such as Nandakini, Mandakini, Bhagirathi and Song show that none of these contribute significant organic load to the river Ganga as shown by the high values of DO and low values of COD/BOD throughout.

(ii) The topographical variations along the river stretch result in lower velocities and turbulance in the downstream portions.

(iii) Comparative investigations on the survival of *E.coli* & fecal streptococci in the Ganga water at Haridwar exhibit that :
  (a) The decay rate in the case of fecal bacteria is very high,
  (b) Fecal Streptococci survive longer than *E.coli.*

(iv) The Pristine Quality variations were established for selected locations viz. Nandprayag and Rudraprayag on the Alaknanda river stretch in the Ganga system because :

They represent relatively pure and unpolluted zones of the Upper Ganga; the Alaknanda river stretch being superior to the Bhagirathi river stretch because of lesser ongoing activities and developmental projects in the catchment area.

Title of the Project : **Integrated study of the Ganga Ecosystem between Narora and Kannauj**
(a) General water quality measurement.
(b) Taxonomical studies of Bacteria.
(c) Man-river interaction studies from land use : geographic points of view.
(d) Pesticides and radioactivity in the river water.

Principal Investigator : PROF A. M. SIDDIQI, Aligarh Muslim University, Aligarh.

Termination Date : March 31, 1990 (Project was initiated during March 1987)

Objectives :
(a) To characterize physical, chemical and biological regime between Narora and Kannauj.
(b) To quantify the present sources of pollution in the reach of the study.
(c) Taxonomical studies of bacteria in the river water.
(d) Assessment of the river productivity and fishery resources.
(e) Effect of pollution on aquatic life.
(f) To determine the influence of geological formations in catchment/recharge basin on the water quality.
(g) To study the interaction of the river and human settlements and effect of land use on the water quality.
(h) Water quality surveillance.

Title of the Project :
(i) Physico-chemical studies of the Ganga water from Kannauj to Shuklaganj.
(ii) Biological studies of the Ganga Ecosystem between Kannauj and Shuklaganj.

Principal Investigator :
(i) DR U. K. Pandey, D.B.S. College, Kanpur.
(ii) DR A. C. Shukla, Christ Church College, Kanpur.

Termination Date : June 1989 (Project work initiated during September 1987)

Objectives :
(i) The objectives of the physico-chemical studies of the Ganga are :
  (a) To characterize the water quality by estimating physical and chemical parameters at various sites between Kannauj and Shuklaganj,
  (b) Physico-chemical analysis of effluents and the total amount of effluents joining the Ganga.
(ii) The objectives of the biological studies of the Ganga ecosystem are :
  (a) To evaluate the river water for its microbial quality,
  (b) To find the planktonic density and identify the indicator organisms,
  (c) To study the nature of benthic flora and fauna,
  (d) To identify the effects of pollution on fish fauna in the river.

Highlights of the Results

Biological profile of the Ganga is rich in qualitative and quantitative abundance of microorganisms, hydrophytes and fish, especially algae. Wide microbe mileu speaks about complexity of the river water in time and space. Role of algae in self-purification, as indicator organisms, and multiple sources of utility in agriculture and fisheries is vital. Disease spread by coliforms, keratino philic fungi, and algal and fungal allergins pose severe public health hazards. Observations emphasize the need for judicious exploitation of the river ensuring healthy water quality. Biological organisms have both beneficial and harmful attributes and which of the two outweighs other is difficult to discern. How best it could be tailored for the benefit is a million dollar question. Truly the Ganga is a water marvel par excellence.

Title of the Project :
(A) A comprehensive study of the Ganga and its dependents. (Kalakankar to Phaphamau)
(B) Environmental Awareness Programme.

Principal Investigator : DR A. K. SINHA, Feroze Gandhi College, Rae Bareli.

Termination Date : Sub-Project A : 30th June, 1988
Sub-Project B : 30th September, 1988

Objectives : (i) Physico-chemical analysis of water for ten sampling stations between Shuklaganj and Kalakankar.

(ii) The macrofloral studies include the survey, collection and identification of flora in the stretch.

(iii) Heavy metal analysis of the river water and sediments.

(iv) Phytoplankton and Zooplankton density and diversity.

(v) Analysis of the gut contents of fishes and listing of endo and ectoparasites of fishes.

Highlights of the Results Data reported can be very helpful in forming a baseline data on physico-chemical and biological aspects of the river.

The report can help in preparing a compendium on macrophytes growing on the banks of the river Ganga. Pollution tolerant species of macroflora and macrofauna can be outlined.

SUB-PROJECT – A

Title of the Project : **Plant population, community structures and function of riparian and aquatic macrophytes in relation to pollution of the river Ganga.**

Principal Investigator : DR R. S. AMBASHT, Banaras Hindu University, Varanasi.

Termination Date : 31st July, 1988

Objectives : (i) Macrophytes density and species diversity; dominance in respect of effluent discharge points.

(ii) Change in macrophytes population with reference to the river water current, silt load and water flow course change.

(iii) Nutrient availability, its uptake and production of macrophytes.

(iv) Studies pertaining to riparian ecology such as nutrient content and changes in it during floods. Native species of riparian ecosystem and their role in water conservation and soil erosion check. Productivity and energy conserving efficiencies of riparian ecosystem.

(v) Models on water quality macrophytes and riparian ecosystem and to integrate these.

Highlights of the Results Phyto sociological analysis and nutrient uptake showed four species to have a higher accumulation capacity for nutrients. Of these *Eichhornia crassipes* and *Hydrilla verticillata* showed widest range with respect to type and content of nutrients. Periodical harvesting of these species can reduce pollution and percent eutrophication.

Significant depletion in riparian vegetation was observed resulting in soil erosion, loss of aesthetic appeal, and economic losses to landowners. Effective measures of riparian ecosystem have been outlined. These are :

(i) Establishment of vegetative and structural measures for erosion control, filtering sediment from adjacent uplands and bank stabilization work.

(ii) Prevention of pollutants from entering the river.

(iii) Revegetational programme to stabilize eroding banks should receive first priority. Fast growing riparian shrubs, such as *Saccharum bengalensis, Alhagi pseudoalhagi, Chrozophora rottleri, Xanthium strumarium* etc. and fast growing trees such as *Leucaena leucocephala, Acacia* sp.,*Salix* sp. which can be effectively grown on riparian lands should be planted at high densities to resist bank scour. Experimental results show the effectiveness of different species for soil, water and nutrient conservation. It is necessary to maintain a well vegetated buffer strip on upper region on the river bank.

SUB-PROJECT- B

Title of the Project : Physico-chemical and Biological characterization of the river Ganga in relation to Pollution.

Principal Investigator : DR B. D. TRIPATHI, Banaras Hindu University, Varanasi.

Objectives :

(i) Origin, nature and intensity of pollutants and their impact on physico-chemical and biological properties of the river water and growth behaviour of some important crop plants.

(ii) Distribution, degradation and biological magnification of pollutants in the river water.

(iii) Eco-modelling of the pollution load, nutrients cycling and energy flow in the river ecosystem.

Highlights of the Results

The use of aquatic plants such as *Eichhornia crassipes* and a few other forms of algae, is the cheapest method of sewage treatment. There is an urgent need for further evaluation of ecological efficiency of other aquatic plants for the sewage treatment.

Title of the Project : Physico-chemical and physiological assessment of heavy metal pollution in the river Ganga.

Principal Investigator : DR L. C. RAI, Banaras Hindu University, Varanasi.

Objectives :

(i) Study of seasonal changes in physico-chemical characteristics of water.

(ii) Measurement of heavy metal contents by AAS.

(iii) Systematic and ecological studies of phytoplankton, nanoplankton and benthos.

(iv) Studies on spatial changes in metal contents in water, phytoplankton, benthos and sediments and their adverse effects on algae.

(v) Determination of autotrophic and heterotrophic biomass of ATP and chlorophyll–a measurement method to study the damage due to release of toxicants.

(vi) Isolation of certain suitable algal strains frequently encountered in the Ganga water.

(vii) Laboratory studies on selected algal strains for heavy metal effects.

Highlights of the Results

(i) Studies on effects of heavy metals on various physiological processes of algae showed low enzyme activity with higher concentrations of Fe (Iron) which is more toxic as compared to other metals.

(ii) Metal supplemented waste promotes the growth of Cyanophyceae and decreases the number of Chlorophyceae, Bacillariophyceae and Euglenophyceae.

(iii) Low rates of $^{14}CO_2$ fixation were observed in metal supplemented water than in natural water.

(iv) Impact of metals on pigment diversity and autotrophic index shows an increase in carotenoid content in comparison to Chlorophyll–a in metal supplemented samples.

Title of the Project : Pollution of the river Ganga with heavy toxic metals.

Principal Investigator : DR. D. C RUPAINWAR, Banaras Hindu University, Varanasi.

Termination Date : 31st July, 1988

Objectives :

(i) A survey on the presence of the heavy metals with special reference to Pb, Cr, Cd, Zn and Hg.

(ii) Periodic data on the presence of heavy metals in (a) river, (b) industrial effluents/sewer discharge, and (c) various sediments to find the pattern of distribution of heavy metals in water, aquatic biota and sediments and their inter-relationships as also their binding capacities based on the textural studies of the sediments.

(iii) Development of suitable and appropriate methods for the pre-treatment of industrial effluents and/or sewage water.

(vi) To investigate and get quantitative information regarding the incidence of diseases associated with heavy metal doses amongst the rural population along the 25 km stretch from Varanasi (main) sewer discharge to Rajghat.

Highlights of the Results Nine sampling stations at Varanasi and four at Mirzapur have been selected for water quality analysis including metals in the Ganga water.

(i) The presence of heavy metals such as Cu, Cd, Co, Pb, Ni, Mn and Zn mainly at the confluence of the sewers and the river indicates that the heavy metal pollution is concentrated at certain points.

(ii) The analysis and critical evaluation of dissolved oxygen and heavy metals at sewer-river confluence points and mid stream points during the years 1986 and 1987 reveal that the pollution abatement measures have shown a significant positive trend and also that the self purification capacity of the river has been increased.

Title of the Project : Coordinated Study of the river Ganga : Civil Engineering Aspects.

Principal Investigator : DR U. K. CHOUDHARY, Banaras Hindu University, Varanasi.

Objectives : (i) The Assessment of Pollutants – quantity and quality reaching the river body through surface media.

(ii) Effluent dispersion in the river.

(iii) Ground water quality and its flow condition.

(iv) River Geometry and its flow behaviour.

(v) Variation in river water surface (RL) and sediment load.

(vi) The methodology for the assessment and management of pollution load with the help of the Ganga laboratory physical model.

Highlights of the Results (i) The dilution, diffusion, dispersion and digestion potentialities of river are the functions of space and time and the quality, quantity and approach condition (including the confluence angle) of the effluents.

(ii) Near the river bank, there are several pockets of reversal flow zones. If pollutants are discharged in the pockets its effect continues to several kilometres in downstream and to some distance in up stream also.

(iii) The pollution managing potentialities of the stream is quite erratic and difficult to be defined purely on the basis of hydro-dynamic equations.

(iv) The pollutants, directly or indirectly affect ground water and river water; therefore impact of treatment plants must be assessed.

(v) The quality, quantity and discharge points into the river of the industrial effluents must be assessed before discharging them (treated or untreated) into the river.

(vi) Cross-sectional shape of the river is changing every year; therefore lateral shifting of the river need to be controlled by proper revetment and aforestation.

(vii) For assessment and management of pollution, a physical laboratory model was constructed to scale for a stretch of 30 kms, for investigating water flow and dilution factors on geometrical, kinematic and dynamic similarities.

Title of the Project : **Coordinated Study of the river Ganga : Study of the river water pollution at Varanasi and prevalence of gastro-intestinal morbidities.**

Principal Investigator : DR I. C. TIWARI and DR P. C. SEN, Banaras Hindu University, Varanasi.

Objectives :
(i) To carry out studies on physico-chemical and bacteriological characteristics of the Ganga water at major bathing ghats and points of sewage discharge.
(ii) Surveillance of gastro intestinal morbidities, outbreaks and mortalities in the city and to collate this data in terms of pollution load in the river and influx of pilgrim population.

Highlights of the Results
The results indicate that bathing ghats and the discharge of untreated sewage have contributed considerable pollution in the river Ganga at Varanasi and the water is no more fit for human consumption.

Title of the Project : **Hydrogeological study regarding the pollution of the river Ganga. (Hydrogeological aspects)**

Principal Investigator : DR G.C. CHOWDHARY, Banaras Hindu University, Varanasi.

Objectives :
(i) *Geological Aspects* – Preparation of topographic maps incorporating the water sources draining in the Ganga, ground water quality of tube and dug wells with special reference to concentration of nitrate, potassium and phosphate.
(ii) *Chemical Aspects* – Trace metals in tube and dug wells.
(iii) *Geohydrological Studies* – Monthly variations in water tables, aquifer constants like storage coefficients, transmissibility and permeability with their role in movement of underground water.
(iv) *Management Aspects* – Identification of sources of pollution for surface and ground water and control of pollution of the Ganga for optimum use of ground water.

Highlights of the Results
(i) Pockets with ground water having more than the prescribed value of nitrate, potassium and phosphate added mostly through fertilizers, nutrients and other elements including toxic substances reaching through various sources have been identified.
(ii) The character of the Ganga basin as a whole is that of "Catchment" with respect to underground water as evident from the SEE and NNW directions of slope of the north and south banks of the river Ganga respectively.
(iii) The drainage system of the Ganga Basin is typical "parallel type" with tributaries meeting the river at an acute angle, giving all opportunities for surface water mixing with the Ganga water and travelling downstream.
(iv) There is a possibility of a free underground passage of pollution through loose sediments comprising mostly of sand silts and pebbles, adding non point load and heavy metals to the river.

Title of the Project : **A study of the submerged and aquatic plants of medicinal and anti-pollutant value in reference to the Ganga water pollution.**

Principal Investigator : PROF R. H. SINGH, Banaras Hindu University, Varanasi.

Termination Date : 31st July, 1988

Objectives : (i) A survey of submerged and aquatic flora of the Ganga water and adjoining area from Mirzapur to Ballia.

(ii) Identification and Pharmacognostic studies on available plants.

(iii) Study of medicinal properties of these plants involving chemical and pharmacological investigations including antimicrobial activity.

(iv) Study of antipollutant and pollutant properties of the surveyed plants (antimicrobial and mineral absorption).

(v) To develop a strategy for economic exploitation of these studies and to develop a model for the same, in reference to their uses and large scale utilization in drug/food industry.

Highlights of the Results (i) 142 plants representing 70 genera and 90 species were collected and their habit, habitat, density and availability were noted.

(ii) *Phytochemical Studies* – 120 plants were qualitatively screened for presence of alkaloids, steroids, terpenes, tannins, saponins, oils etc.

(iii) *Nutritional Value* – Leaf protein concentrations of plants and evaluation of their food value.

(iv) Mineral contents such as Na, K, Ca, Mg, and Fe were estimated for plants, polluted and unpolluted water samples.

(v) Extracts from 20 plant species were screened for antibacterial activity against 10 species of common pathogens.

(vi) Anti pollutant activities were studied for some of the aquatic plants and it was found that important inorganic pollutants were taken up by the aquatic species.

Title of the Project : **Role of sediment in attenuation of trace metals in polluted aquatic environment of the river Ganga : Sedimentological aspects.**

Principal Investigator : DR M. N. MEHROTRA, Banaras Hindu University, Varanasi.

Termination Date : 31st July, 1988

Objectives : (i) Identification of sources of pollutants and their quantification in industrial effluents, sewer discharged and river water.

(ii) Study of dispersion of toxic metals in sediments (Textural, mineralogical and chemical studies).

(iii) To suggest/develop methods for attenuation of toxic metals in the polluted aquatic environment.

Highlights of the Results Analytical work with regard to grain size behaviour, dispersion of toxic metals in the sediments, organic carbon and organic matter analysis and surface textural studies through electron microscope have been carried out.

(i) The studies revealed that sediments have varying quantities of toxic metals. The widely varying metal absorption capacity is attributed to the composition of the sediment, particularly its clay minerals. Therefore, the sediments, particularly its clay minerals, composition could be considered significant for attenuation of the toxic and hazardous metals of the river Ganga.

(ii) Suggestions for controlling the aquatic pollution and conserving the water quality include chemical flocculation, dewatering and stabilization and chemifixation etc.

(iii) Membrane filters, chelex and UV irradiation have been suggested for dredging of the sediments which is to be carried out in conjunction with the river regulations and land fill project has also been suggested. However, the economic viability of these methods is yet to be examined.

Title of the Project : **Impact of heavy metal pollution in the river Ganga on fish.**

Principal Investigator : DR A. K. MITTAL, Banaras Hindu University, Varanasi.

Objectives : The aim of the project is to study the impact of heavy metals, enriching the river Ganga sediments which are considered as most notorious pollutants, on the physiology of fish using tissue culture techniques. The useful information on effect of toxicants at cellular level in fish would serve in protecting the fish community which is a rich protein source.

Title of the Project : **Water pollution and endocrine imbalance with special reference to high thyroid physiology and reproduction in some important food fishes.**

Principal Investigator : DR T. P. SINGH, Banaras Hindu University, Varanasi.

Objectives :
(i) Sample collection (fish) from the effluent sites.
(ii) Blood osmolality, Thyroxine and Tri-iodothyronine measurement.
(iii) Reproductive status by GSI-2 for correlation between thyroid physiology and reproduction to be ascertained.
(iv) Three varieties of carps to be studied.

Highlights of the Results
(i) LC50 values for BHC and malathion established for *Heteropneustes fossilis*.
(ii) Radio-immunoassay of thyroxine and trio-iodothyronine.

Title of the Project : **A study of the river Ganga with reference to environmental and socio-economic awareness (extension activities)**

Principal Investigator : DR KRISHNA BAHADUR, Banaras Hindu University, Varanasi.

Objectives :
(i) To locate the social and economic evils found and practised by the prople inhabiting the Ganga belt.
(ii) To analyse the reasons for the degeneration and eradication of social and moral values amongst the people living in the Ganga belt.
(iii) To suggest improvements, modifications and dropping down of ineffective and inadequae methods and adoption of such further methods as would help in the timely and effective awareness of problems related to environment and socio-economic life.

Highlights of the Results
(i) There is a total lack of knowledge about the problems and causes of the pollution of the river Ganga in the masses.
(ii) The general public does not know the terms such as (a) Treatment, (b) Water Recycling Unit, (c) Bio-gas, (d) Pollution, (e) Environment etc. The time is now ripe to tell them how scientifically the water can be cleaned under GAP.
(iii) Traditional rights of citizens to throw dead animals from Gaighat may be discouraged and an alternative arrangement be made.
(iv) Research Programmes may be divided into two parts viz. one to deal with the research aspects and other with the implementation of research.
(v) A number of steps have been proposed for creating environmental and socio-economic awareness. These are :
    (a) Advertising through T.V. and Radio,
    (b) Small public gatherings,
    (c) Torch processions,

(d) Wall slogans, posters, leaflets, pamphlets, brochures, calendars, pictures, book marks etc.,

(e) Sign boards on the Ghats,

(f) Individual contacts,

(g) Meetings and Group discussions,

(h) Workshops, Seminars, Conferences,

(i) Training and Refresher courses,

(j) Cultural programmes, Folk dances, Dramas etc,

(k) Establishment of an Institute for Pollution Awareness.

A monthly journal to be called "Ganga Gyan Mala" has been proposed for publishing.

Title of the Project : Coordinated study of the river Ganga (agricultural aspects), Mirzapur to Ballia.

Principal Investigator : DR R. C. TIWARI, Banaras Hindu University, Varanasi.

Objectives : (i) To study the seasonal/monthly variations in the quality of the Ganga lift canal irrigation water on the basis of detailed chemical analysis.

(ii) To find the effect of the Ganga lift canal irrigation water on some important physico-chemical characteristics of soil of canals command areas.

(iii) To study the effect of the Ganga lift canal irrigation water on different crops grown in different soils in comparison with tubewell irrigation of adjoining area.

(iv) Subjective survey of the farmers of the Ganga lift canal command area to assess their views on changes in agricultural situation particularly influence of irigation on soils, crop quality, crop substitute and water table of the same areas etc.

Highlights of the Results (i) The studies on the quality of the Ganga lift canal waters have revealed that the irrigation water falls under class C_2 S_1 which indicates that water can be safely used for irrigation for almost all type of crops (pulse and cereals) with a little danger or no sodium accumulation at harmful levels. In heavy soils where permeability is low, the irrigation may develop salinity hazards. The *p*H and EC values for different seasons fall as March-June > November to February > July to October.

(ii) The comparative studies made on effect of the Ganga irrigation water and tubewell irrigation (for at least 10 years) on soils irrigated with both waters respectively have revealed that Ganga irrigated soils have higher organic carbon (%), sand and silt (%) and NPK content than tubewell irrigated soils. This indicates pollutants load in the Ganga water.

(iii) The crops (Moong bean, Rice and Wheat) irrigated with the Ganga water have shown higher grain and straw yields than tubewell irrigation water. There were some differences in yields of the same crop when irrigated with canal waters of different locations at stretch of 255 kms.

(iv) The subjective survey of the farmers of the Ganga lift canal command area (50 farmers from 5 villages of each canal command area) have indicated that, canal irrigation was good, yields of wheat and rice have increased tremendously, but the crops such as pulses, oil seeds and coarse grains have practically vanished from the area after inception of canal irrigation. The orchards of fruit and other trees have wilted due to higher water table. The weed menace and mosquito population have increased. The command area is cooler than ever.

Title of the Project : An inter-disciplinary study on the problems of water pollution of the river Ganga with special reference to identifying biota and their role in rehabilitating the river water, sedimentation and specification studies, data generation, collation, analysis and mathematical modelling of the river quality and carbon cycling. Buxar to Barauni)

Principal Investigator : DR R. K. SHARAN, Patna University, Patna.

Termination Date : 30th June, 1988

Objectives :

(i) Qualitative and Quantitative estimation of phytoplankton, zooplankton, macrozoobenthos, fishes and other macrofauna and fungi.

(ii) To evaluate species diversity and biotic indices to assess the pollution level of the river.

(iii) To assess the role of biota in rehabilitating the river water.

(iv) Sedimentation and speciation studies.

(v) Study of detritus in relation to pollution eutrophication, energy-flow and carbon cycling in the river ecosystem.

(vi) Physico-chemical characteristics including the levels of total coliform, *E coli,* Fecal streptococci.

(vii) Study of heavy metals, pesticides, fertilizers and phenolics in the river water and sediments.

Highlights of the Results

In this stretch of the river the density of phytoplankton was observed to be poor and they mostly belong to Chlorophyta. Some of the phytoplankton namely *Merismopedia* sp., *Hydrodictyon* sp., *Pediastrum* sp., *Melosira* sp., *Cladophora* sp., *Rhizoclonium* sp., and *Ulothrix* sp. have been found to be good indicators of good water quality. *Spirogyra condensata, Lyngbya* sp. and *Oscillatoria* sp. have been encountered as freshwater pollution algae.

A total number of 31 species of zooplankton was identified, of which 17 belong to Rotifera, 7 to Cladocera, 6 to Copepoda and one to Ostracoda. Rotifers dominated the planktonic fauna, especially Branchionidae. *Testudinella* sp. and *Hexarthra* sp. were for the first time recorded from the Ganga.

Three species of Polychaeta and one new species of this group have been identified for the first time, probably, from freshwater body of India. A total of 33 species of macrozoobenthos have been collected and identified and they belong to Polychaeta (4 sp.), Oligochaeta (4 sp.), Insecta (8 sp.), Gastropoda (6 sp.) and Pelecypoda (11 sp.). The maximum population upto 50,000 individual/of tubificids was recorded near outfall points.

57 species of fishes, 3 of Amphibia, 5 of Reptilia, 22 of Avian fauna and one of mammal (*Platanista gangetica*) have been identified.

54 species of Fungi have been isolated and identified from the river sediments while 51 species from water. *Aspergillus* was found to be the dominant genera with eleven species both in water and sediments. Three aquatic fungie viz. *Achlya* sp., *Saprolegnia* sp. and *Aphanomyces* sp. were isolated from water and soil samples by baiting technique.

The Shannon and Weiner species diversity index of Benthic macro-invertebrates varied between 2.281 at Buxar upstream, the entry point of the Ganga in Bihar to 0.322 near Patna, which is the most polluted zone of the river. Based on this index it was concluded that the river is moderately polluted in this stretch and the degree of pollution is more near Patna than at other stations.

All the benthos specially the polychaetes were found to be detritivores, thus reducing the detrital load of the river. The Ichthyofauna were dominated by catfishes which mainly feed on dead bodies, caracasses and detritous. This again has direct bearing on the rehabilitation of the river water.

Due to low gradient and the confluence of four major tributaries of the Ganga in this stretch the sedimentation rate is high specially in and around Patna. This has resulted in a vast stretch of Diara land in this region.

The detritus load (dry wt.) gm/m^2 varied between 4.96 during winter at Barh (D/S) to 0.23 during Monsoon at P.M.C.H., Patna. The organic carbon percent of the detrital material was minimum during Monsoon (7.94 %) followed by Summer (8.63 %) and maximum (10.52 %) in winter. The higher organic carbon content in winter may be due to low temperature, low bacterial activity and cosequently less solubilization of the organic carbon into dissolved organic carbon.

The river receives the detrital load through discharge of domestic effluents causing Eutrophication - like condition at certain points near Patna resulting in highest degree of pollution. This results in an increased organic carbon content of sediments, as is evidenced at P.M.C.H., Patna which has highest carbon percentage (2.59). It would not be out of place to mention here that though Barh (D/S) has the maximum detrital load in the form of leaf litters etc., the sandy nature of bed does not allow retention of organic load and Eutrophication resulting in less pollution of water.

Carbon cycling and energy flow in the river Ganga has only been partially worked upon in the present study. Besides the organic carbon flow through detritus and sediment mentioned earlier, the flow through different benthos has been estimated. The primary productivity (0.92-1.59 kg.C/m^2/yr.) was evaluated in this stretch of the river. The secondary productivity (benthos) fluctuated between 66.82 to 1.05 gm/m^2 (dry wt.) and the carbon percent was in the range of 40.3 to 7.74.

The physico-chemical characteristics of the river water was estimated to be as follows–water temperature (18.9-35.0 deg. C), Transparency (4.9-58.7 cm.), *p*H (7.0-8.2), D.O. (4.2-10.2 mg/L), free CO_2 (1-15.0 mg/L), Carbonate alkalinity (2.0-15.4 mg/L), Bicarbonate alkalinity (70.2-276.0 mg/L), Hardness (73-230 mg/L), Calcium (10.0-61.32 mg/L), Magnesium (3.2-23.1 mg/L), Chloride (2.8-41.9 mg/L),COD (4.6-51.2 mg/L), BOD (2.7-13.6 - mg/L), Phosphate Phosphorus (0.002-0.23 mg/L), Nitrite Nitrogen (0.01-0.38 mg/L) and Sulphate (6.2-71.04 mg/L). The results indicate low to mild pollution of the river water which is also of calcium-rich type in the stretch under study.

The bacterial density (CFU/mL × 10^3) in the river water varied between 0.1-17.6 (E. Coli), 8.1-99.7 (Enterobacteriaceae), 0.8-39.1 (total coliform) while their levels in sediments (CFU/gm. × 10^3) were 10-7963 (E. Coli), 602-64, 365 (Enterobacteriaceae) and 34.5-19013 (total coliform).

The average concentration of heavy metals (in ppm) in river sediment is Ni (83), Co (80), Cu (358), Zn (176), Cd (15) and Pb (209). The concentration of Ti and Fe (Wt. %) is 0.45 and 3.52 respectively. The highest concentration (in ppm), of Ni (100), Co (103), Cu (391), Zn (225), Cd (20) and Pb (237) were observed at Barh, Buxar (town), P.M.C.H., Patna, Gandhi Setu Patna and Buxar (U/S) respectively.

Title of the Project : **Co-ordinated Study of the Ganga Ecosystem from Patna to Barauni. (Barh to Sultanganj)**

Principal Investigator : DR A. K. SRIVASTAVA, Rajendra Agricultural University, Samastipur.

Objectives :

(i) Identification of the sites with different characteristics of pollution in the Ganga from Barh to Sultanganj.

(ii) General survey and population study of the primary producers, bacteria and some important microfauna and to assess their indicator value for the quality and quantity of pollution in different zones.

(iii) Identification and evalulation of the primary producers as terrestrial natural flora, specially the grasses, on the banks of the Ganga and to analyse their productive potential, soil binding capacity and indicator value for the quality of pollution in adjoining the belt of the Ganga.

(iv) Physico-chemical analysis of the Ganga water and sediments, specially with respect to heavy metal and other toxicants and the analysis of general micro-environment.

(v) Identification of bio-indicators of the Ganga water.

(vi) Modelling of system in operation in the Ganga with respect to different aspects of pollution in the zone from Barh to Sultanganj based on the data collected representing almost the full spectrum of the Ganga in this zone as a holistic approach.

Highlights of the Results (i) The DO content of the river showed a range between 5 and 12.6 mg/l.

(ii) The BOD showed maximum values at Mokameh (0.82 – 6.56 mg/l) during summer season.

(iii) The phytoplankton density ranged from 125.5 – 157.5 u/l at Barh. Sultanganj gave the maximum phytoplankton density of 222.5 (Number 10/ml).

(iv) The fungal population was lowest per gram of wet soil for Barh (6 × 10) in January, 1987 while Mokameh showed highest fungal population 24 × 10 during May, 1987.

(v) Actinomycetes density and identification have been carried out. Munger showed the maximum density and number of genera for Actinomycetes (49 × 10).

(vi) 63 algae belonging to various classes such as Cyanophyceae, Chlorophyceae, Xanthophyceae, Euglinidae, Rhodophyceae and Bacillariophyceae were identified from various sampling stations.

Title of the Project : Study of the river Ganga from Monghyr to Farakka. (Barauni to Farakka)

Principal Investigator : DR K. S. BILGRAMI, Bhagalpur University, Bhagalpur.

Termination Date : 30th April, 1988

Objectives : (i) To evaluate the Ganga water for physico-chemical and biological quality.

(ii) Biomonitoring of water quality through selective indicator organisms.

(iii) Role of biopurifiers-Bacteria, Fungi and Algae.

(iv) Heavy metal analysis in benthic sediments.

(v) Study of food chain in the river on the basis of gut contents of fishes and zooplankton.

(vi) Impact of floods on microbial population of the river and productivity of Diara land.

(vii) Effect of agro-chemicals, phenolics and pesticides on water quality.

(viii) Study of chemical nature of fat of the Ganges dolphin.

Highlights of the Results

From physico-chemical angle the water quality of the Ganga in Munger-Farakka range shows degradation at the points of urban concentration and industrial units which adversely affect the primary and secondary productivity. Biomonitoring, besides being quick and convenient, can serve as a fairly accurate tool for determining the water quality. In heavily polluted segments the concentration of indicator bacteria like MPN of total coliform, and fecal streptococci is high. The density of pollution tolerant algal forms such as *Oscillatoria chlorina, O. tenuis, Phormidum uncinatum, Spirulina major, Chlorella vulgaris, Ankistrodesmus falcatus, Schizomeris leibleinii, Stigeoclonium tenue, Euglena acus, E. viridis, Navicula viridula* was much more higher at sewage discharge points. Role of bacteria and fungi as biopurifier is accomplished through their decomposing activity of the bulk organic matter produced in the aquatic environments while some of the algae biopurify the water through bioaccumulation of toxic materials. Of the different heavy metals analysed Cu, Zn, Fe, Cr, Mn and Ag were present at all the sampling sites in benthic sediments in variable concentrations. Concentration of Fe was much beyond the permissible limit. Study of food chain in the river was performed by analysing the gut content of herbivores (*Daphnia, Macrobrachium, Epherella, Pila, Rhinomugil* and Tadpole larva), Omnivores (*Catla* and *Clupisoma* fish) as well as Carnivores (Nymphs of *Mesogomphus, Rita, Glossogobius* & *Wallago*). MPN of total coliform and fecal streptococci as well as fungal population were recorded highest during the floods. The total primary production of diara land could not be evaluated during flood because of almost complete submergence of the land areas. Apparently, it was negligible. Agro-chemicals, phenolics and pesticides adversely affected the water quality, which was evidenced by low DO, high BOD, low *p*H and increase in temperature and turbidity. Ganga dolphin contains two major fat components i.e. Urethane and Benzoate which serve as attractants for other fishes.

Title of the Project : **Biotic communities and productivity of the river Ganga and its bunds as affected by pollution.**

Principal Investigator : PROF K. R. SAMADDAR, University of Kalyani, Kalyani.

Termination Date for Sub Project A, B & C : 31st March, 1987

Objectives :

(i) Bio-monitoring of pollution load of the river water and to assess the population dynamics of pollutant bacteria as affected by industrial effluents.

(ii) Effect of polluted water and industrial effluents on distribution pattern of macrophytes and diazotrophic N_2 fixers.

(iii) Population dynamics of fungi, sewage bacteria and phages, seasonal variations and cytogenetic effects of polluted waters.

Highlights of the Results

(i) Effects of paper mill effluents on macrophytes and effects of industrial toxicants on the population dynamics of diazotrophs in soil bacteriological quality showed significant number of total coliform, fecal coliform (FC), Salmonelle, fecal streptococci (FS). High FC/FS ratio indicates pollution from human sources.

(ii) Density of fungi in the river estimated, role of bacteriophages in reducing the pollution load and cytogenetic effects of the river pollution studied.

Title of the Project : **Bio-ecological studies of the river Ganga with special emphasis on various aspects of the river fauna as affected by pollutants and restoration of normal faunistic pattern.**

Principal Investigator : DR S. P. BHATTACHARYA, University of Kalyani, Kalyani.

Objectives :

(i) To study the physico-chemical characteristics of the waste discharge of some industries.

(ii) To determine the concentration of pollutants of different organs of fresh water fish.

(iii) To study in detail the deleterious effects of some of the highly toxic industrial pollutants (namely phenol, sulphide, mercury, cadmium, lead etc.) present in the factory drainage and in the river Ganga in different concentrations on the bio-chemical and physiological aspects of reproduction of fresh water carp by studying the various parameters with special emphasis to steroidogenesis and the pattern of their recovery.

(iv) Relationship between pollution load and growth of fish.

Highlights of the Results (i) Observations were made on the fish fauna, migration of fish, fish breeding of major Indian Carps and different sources of pollution.

(ii) Results indicated heavy industrial and domestic pollution in the study zone causing deposition of silt on the river bed. A gradual change in ecological features affecting the population of fishes was observed.

(iii) Effect of industrial pollutants on reproduction of fish was also studied.

Title of the Project : **Physico-chemical studies of the river Ganga for the rehabilitation of the polluted water and development of analytical methods. (Katwa to Naihati)**

Principal Investigator : PROF R. SEN GUPTA, University of Kalyani, Kalyani.

Objectives : To investigate and establish certain physico-chemical parameters of the polluted water with special emphasis on tannin, lignin, detergents, heavy metals and phosphorus cycle.

Highlights of the Results Physico-chemical parameters like *p*H, hardness, BOD, COD, alkalinity, acidity, TDS, carbonate etc were determined. Methods for determining tannin, lignin and detergents in the water were developed. Heavy metal analysis done by methods other than AAS. X-ray diffraction method was used for studying pollution effect on water structure.

Title of the Project : **Socio-economic maladies created by deteriorating hydrofluvial region of the Ganga and to suggest measures for their amelioration.**

Principal Investigator : PROF K. G. BAGCHI, University of Calcutta, Calcutta.

Termination Date : 11th February, 1987

Objectives : (i) Reconnaissance survey of the river banks to outline the problems.

(ii) Overall demographic pattern, occupational structure.

(iii) Terrain pattern and land use pattern.

(iv) Water supply and Drainage systems outline.

Highlights of the Results (i) Present environmental status has been assessed by studying the physiography, flow character and sedimentation.

(ii) Information on land use pattern, soil and climate conditions, industrial status, demography for two districts namely Hugli and 24 Parganas obtained.

(iii) Quantitative requirements of water, type of drainage and sewage system and transport have been carried out.

(iv) Identification of problems associated with the deterioration of the Ganga such as Navigational problems, fishing, health hazards etc. has been done.

Title of the Project : **(i) Survey of Agro-chemicals (fertilizers, pesticides etc.) in the riverine land and its impact on the level of pollution of the Ganga water.**

(ii) Awareness Programme. (Bally to Bandel)

Principal Investigator : PROF T. M. DAS, University of Calcutta, Calcutta.

Termination Date : 31st March, 1988 (11th Feb. 1987 for awareness programme)

Objectives : (i) Survey of the use of fertilizers and pesticides in the Agriculture of the riparian land as well as the amount of these ultimately washed out and mixed up in the Ganga water.

(ii) The detection as well as concentration of non-biodegradable pesticides in the Ganga water, in plants and fishes to be determined by G.L.C.

Highlights of the Results

(i) 50 maps and 30 descriptive charts prepared to show the types of crops grown, nature of pesticides and fertilizers used and locations of industries.

(ii) Ten municipalities on the west bank of the river and 8 on the east bank identified. Land use patterns and fertilizer consumption have been outlined. Concentrations of N, P, K and pesticides have been estimated.

(iii) Heavy metal estimations for Mn, Cu and Zn done for the Ganga water

(iv) Experiments on effects of the Ganga water on germination from fertilizer factory.

Title of the Project : **Effect of pollution on biological health of the Ganga water and devising remedial measures.**

Principal Investigator : PROF N. C. DATTA, University of Calcutta, Calcutta.

Objectives :

(i) To assess the physico-chemical properties of water.

(ii) To collect baseline information on the qualitative and quantitative abundance of biotic communities of the river Ganga.

(iii) To make an attempt to identify the bio-indicators of pollution and bio-purifiers.

Highlights of the Results

The main objective is to obtain a baseline information on the qualitative and quantitative abundance of biota of the river Ganga. 15 parameters analysed to estimate the Physico-chemical quality of water. These are temperature, turbidity, EC, *p*H, DO, carbonate, bicarbonate alkalinity, total alkalinity, hardness - calcium and magnesium, dissolved organic matter, chlorinity, P, N, Silicate, BOD. The biological parameters measured include qualitative and quantitative analysis of phytoplankton, periphyton, zooplankton, macro-zoobenthos and qualitative analysis of macrophytes.

Title of the Project : **Characterization of pollutants in the Ganga water.**

Principal Investigator : PROF J. DAS, Burdwan University, Burdwan.

Termination Date : 28th February, 1987

Objectives :

(i) Determination of general characteristics including inorganic anion contents.

(ii) Identification and speciation of the metals present in the water samples.

(iii) Characterization of organic materials and the role of humus in the Ganga water samples.

(iv) Analysis of sediments for heavy metals and organic pollutants.

Highlights of the Results

(i) Presence of cadmium is very close to the danger levels (4.63 - 13.89 ppb as against the permissible limit of 10 ppb).

(ii) Existance of titanium, lanthanum, gadolinium and possibly zirconium in the river water is very striking.

(iii) The predominant species among the organic determinants are hydrocarbons, which might be due to higher affinity of humus for polar compounds. The relationship between organic micro-pollutants and humus needs further investigation.

Title of the Project : **Mathematical and statistical analysis of the problems of pollution, erosion, ecology of aquatic population.**

Principal Investigator : PROF S. K. CHAKRAVARTY, Burdwan University, Burdwan.

Objectives :

(i) A model study of pollutant dispersion with reference to cross-sections of the Ganga within the region of study.

(ii) A study on non-linear models of growth of competing animals subjected to retarding factors which might be interpreted as the effect of pollution.

Title of the Project : **Effects of the polluted Ganga water on micro and macroflora in the river and its adjoining area and biological control of pollution.**

Principal Investigator : PROF A. K. BANERJEE, Burdwan University, Burdwan.

Objectives : (i) To study the composition of the micro and macroflora of the river water and adjoining areas and to determine from the data the pollution status of the river.

(ii) To study the effect of the river water on the growth of some macrophytes, like *Eichhornia, Hydrilla* and *Azolla.*

(iii) To study the capacity of these three plants to control pollution level by withdrawal of pollutants from the water.

Highlights of the Results (i) The river water of Behrampur, in general, was cleaner than that of Katwa.

(ii) The fungi isolated from the river water were typically inhabitants of soil (geo-fungi).

(iii) Resistance of isolated bacterial culture showed that the resistance to antibiotics was in the following order :
Benzyl penicillin, streptomycin, tetracycline, gentamycine, chloramphenicol.

(iv) The growth of test plants -*Eichhornia, Azolla* and *Hydilla* resulted in reduction of total suspended solids as well as the concentration of nitrogenous and phosphorus compounds of the water. *Eichhornia* proved to be the most efficient followed by *Azolla* and *Hydrilla* in removing the key nutrients from the growth medium.

Title of the Project : **Harnessing of riverine resources with reference to commercially viable fish species. (Behrampur to Katwa)**

Principal Investigator : PROF D. K. CHOUDHURI, Burdwan University, Burdwan.

Objectives : (i) To analyse different physico-chemical parameters of the Ganga water in the given sector.

(ii) To make a bi-monthly survey of the fish catch made by the local fishermen to comprehend the commercially viable fish fauna of the sector.

Highlights of the Results (i) The value of different physico-chemical factors of the Ganga water are within the tolerable range for fish fauna.

(ii) Gradual reduction in fish catch has been observed. This can be related to two factors :

(a) The sector under investigation is situated between two septic zones – one being Farakka and the other Bandel to Hugli. The latter harbours industrial complexes. This restricts free movement of young carps,

(b) Indiscriminate destruction of juvenile carps in the area of spawning grounds situated at upper stretches particularly Bhagalpur, Lalgola and Haridwar leads to alarming reduction in population of major carps.

(iii) No spawning grounds of fish were found in the stretch investigated.

Title of the Project : **Effects of pollutants of the Ganga on the embryonic and post-embryonic development of some aquatic and terrestrial animals at the cellular / sub cellular levels.**

Principal Investigator : PROF J. N. MEDDA, Burdwan University, Burdwan.

Objectives : (i) To study whether the insecticides methyl parathion and BHC produce any harmful effects on the developmental process of vertebrates.

(ii) To seek the probable causes of the effects at biochemical levels.

Highlights of the Results
(i) Use of insecticides results in abnormalities like impairment of development of CNS, sense organs, limb buds and allentois.
(ii) BHC causes defective development of skull bones in many cases, no eyes and auditory vesicles were formed, embryos in treated animals were significantly smaller than controls.
(iii) Insecticides alter the production and utilization of energy reserve. Anti-fertility action on Swiss albino mice was also shown.

Title of the Project : **Interactions between zooparasitic nematodes and vertebrate hosts inhabiting the polluted bodies of water of the river Ganga.**

Principal Investigator : PROF G. MAJUMDAR, Burdwan University, Burdwan.

Highlights of the Results
(i) A number of vertebrate hosts have been examined but only eight piscine, one amphibian and three reptilian hosts have been found to harbour 12 species of nematode parasites.
(ii) Application of tracer techniques revealed that there is a definite transcuticular transportation of nutritional macromolecules from the niche to the interior organ systems of the nematodes.
(iii) The frequency of occurrence of more nematodes in carnivorous hosts indicates that zooplankton are less effected by pollutants in the stretch between Behrampur and Katwa.

Title of the Project : **Studies on the impact of irrigation and flooding by the polluted Ganga water on the soil fauna of cultivated and uncultivated soils (fields) in relation to fertilizers and productivity of soil.**

Principal Investigator PROF D K. CHOUDHURI, Burdwan University, Burdwan.

Objectives
(i) To study the effect of irrigation/flooding by the Ganga water on the soil fauna of cultivated and uncultivated fields adjacent to the river Ganga in relation to fertility and productivity of soil.
(ii) To study the role of soil fauna in detoxification/degradation of pollutants if any, reaching the field through irrigated water

Highlights of the Results
(i) Uncultivated fields not irrigated by the Ganga water supported a large fauna of arthropods than cultivated ones
(ii) Microbial population was relatively high in uncultivated plots. Bacteria were most abundant followed by actinomycetes and fungi.
(iii) Relatively high level of organic carbon, higher population of micro organisms and absence of probable pollutants might have contributed towards a large fauna of arthropods in uncultivated fields. It is known that the distribution of soil arthropods depends on the microbial flora serving as the source of food. Treatment of pesticides/insecticides on the foliage in agricultural fields and their entry into the soil through rain water might have led to a decline in faunal population.

Title of the Project : **Utilization of human resource : Problems and Suggestions. (Behrampur to Katwa)**

Principal Investigator PROF M. R. CHOUDHURY, Burdwan University, Burdwan.

Objectives : To appreciate in its proper perspective the human responses in the utilization of the Ganga water, the study of spatial situation in its catchment is required to provide a basis for the other aspects of study concerning the Ganga water utilization.

Highlights of the Results (i) Extensive mapping of the nature of slope of the study area comprising of eleven police stations, eight in Murshidabad, two in Burdwan and one in Nadia district, has been done.

(ii) Probable causes of the flood have been outlined and problem of flood water management dealt with.

(iii) The hydrological characterization of the Ganga river basin to throw light on settlement ecology, riparian changes and environmental conditions.

(iv) Land use pattern in the sector under consideration to help development planning based on suitability of land.

SUB-PROJECT - A

Title of the Project : (i) **Awareness Programme Workshop.**

SUB-PROJECT - B

Title of the Project : (i) **Natural properties, transformation of the river sediment and its nutritive value.**

(ii) **Effect of run off pesticides on the water quality.**

Termination Date : 10th January, 1987

SUB-PROJECT - C

Title of the Project : (i) **Microbiology of the polluted water of Hugli.**

(ii) **Role of the Ganga in Epidemiology.**

(iii) **Biological Monitoring of the water quality of Hugli.**

(iv) **Utilization of fungi for biopurification.**

Principal Investigator : DR S. MUKHOPADHYAY, Bidhan Chandra Krishi Viswavidyalaya, Kalyani.

Highlights of the Results (i) Results are indicative of high surface absorptive ability of sediment clays for cationic species of heavy metals and other exchangeable cations.

(ii) BHC, DDT and Endosulfan residues are present in water samples of lower tidal section of the river in appreciably higher quantities.

(iii) Incidence of coliphages from 24 locations revealed the presence of two distinct coliphages, their concentrations being more towards the discharge points of waste waters.

(iv) Population of fungi that are present in waste water environment have been estimated and the role of fungi in degrading the pulp and paper mill effluents studied. 12 species have been selectively obtained by isolation on ligno-cellulosic compounds which are most important soluble, non-degradable pollutant components of paper mill wastes.

SUB - PROJECT - D

Title of the Project : **Propagation of horticultural plants for the conservation of the banks of Hugli river.**

Principal Investigator : DR P. G. MAITY, Bidhan Chandra Krishi Viswavidyalaya, Kalyani.

Highlights of the Results (i) The project seeks to identify the species which will assist in controlling erosion of agricultural lands on the river front.

(ii) 32,000 sq m of inundation and erosion prone area have been planted with 28 tree species.

(iii) Survival, growth and biomass production is under study for selection of suitable tree species.

SUB-PROJECT - E

Title of the Project : **Effect of pollution due to saline tidal water on the ecosystem of the deltaic region and its solution. (Katwa to Bandel)**

Principal Investigator : DR A. K. MUKHOPADHYAY, Bidhan Chandra Krishi Vishwavidyalaya, Kalyani.

Objectives :
(i) Hydrological and soil physico-chemical studies on the genesis, nature and characteristic of ground water and surface soil salinity.
(ii) Micro-biological studies on plants adaptation to saline environment.

Highlights of the Results
(i) Hydraulic continuity of sub-soil is revealed with the tidal water of the rivers and creeks and surface and sub-soil salinity arise due to intrusion of saline tidal water into sub-soil upon tidal influx of sea water.
(ii) Studies on Shizosphore microbiology in relation to plant nutrition of forest and agricultural plants revealed the presence of vasicular arbyscular endophytes in the roots of most species of natural and artificial colonisers of delta land.
(iii) Presence of both aerobic and anaerobic free living nitrogen fixing bacteria in mangrove soils have been detected from most surface soils.

Title of the Project : **Environmental Awareness Programme Workshop.**

Principal Investigator : PROF DILIP BOSE, Department of Chemistry, Jadavpur University, Calcutta.

Termination Date : March 25, 1985

Objectives : To rouse public awareness and concern for the pollution of the Ganga and its basin.

Highlights of the Results
(i) Display ads in leading dailies.
(ii) Press conference with participation by youths, teachers, NGO's & science clubs etc.
(iii) Two day workshop on Environmental Awareness and Control of Pollution in the Ganga (March 24-25, 1984). The recommendations were as follows :
  (a) Awareness Programmes to be sponsored by MOEn
  (b) Pictorial leaflets on environmental or ecological disasters, puppet shows, films, exhibitions through village based organisations, schools, clubs etc. Popular lectures by environmentalists.
  (c) Scientific Model making by youth clubs
  (d) Regional coordination centres to plan, supervise and coordinate awareness activities.
  (e) Amendment of curricula and short term training courses at schools and colleges.
  (f) Development of 'Field Test Kits' for measuring river water pollution for distribution to schools, colleges, NGOs and other action groups.

Title of the Project : **Instrumentation for Pollution Monitoring of the Hugli Estuary.**

Principal Investigator : PROF P. SOM, Jadavpur University, Calcutta.

Termination Date : 30th September, 1987

Objectives : To design and develop an instrumentation system for in *situ* sensing, monitoring, recording and transmitting by telemetry for processing and storage of the essential water quality parameters viz. Electrical Conductivity (EC), Hydrogen ion concentration (*p*H), Temperature (Centigrade), Dissolved Oxygen (DO), and Velocity of surface water bodies with indigenously fabricated hardwares as far as practicable.

Highlights of the Results

(i) The development of circuits, except for velocity are completed for pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), and Temperature (Centigrade) from indigenously available components.

(ii) The reliability of these components can only be estimated by conducting experiments with these curcuits over a prolonged period. The present exercise was terminated at laboratory bench scale level.

(iii) The transmission and reception of constantly monitored data at two stages - from floating buoy to the shore antenna and from the antenna to the state laboratory (Jadavpur University) will need a year's study to evaluate the performance of prototype.

(iv) To explore the availability of a similar bench mark system in the market for comparison and evaluation of the presently developed system

(v) To conduct the pilot study in Hugli Estuary for a period of one and a half year, in collaboration with an entrepreneur to develop the instrumentation kit and telemetering system for commercial production.